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A Summary of Current Program and  
Preliminary Report of Progress

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CITRUS AND SUBTROPICAL FRUIT RESEARCH

of the

United States Department of Agriculture  
and Cooperating Agencies

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.

December 1, 1963

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## ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research and Service
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton and Tobacco Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research

## ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First, there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

### Agricultural Research Service (ARS)

- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite

### Agricultural Marketing Service (AMS)

- 4 - Market Quality
- 4 - Transportation and Facilities

### Economic Research Service (ERS)

- 4,5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Resource Development Economics
- 5 - Economic & Statistical Analysis
- 5 - Foreign Development and Trade Analysis
- 5 - Foreign Analysis Division

### Other Services

- 1 - Soil Conservation Service (SCS)
- 4,5 - Farmer Cooperative Service (FCS)
- 4,5 - Statistical Reporting Service (SRS)
- 6 - Forest Service (FS)

Three organizational unit reports are not reviewed in entirety by any one committee. All of the information in them is included in the subject matter reports.

Agricultural Research Service (ARS)

Agricultural Engineering  
Crops  
Entomology

SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the U.S.D.A. program and progress for the following commodities and subjects:

- |  |   |
|--|---|
| 1 - Cross Commodity Research of<br>Agricultural Engineering, Crops,<br>& Entomology Research Divisions | 7 - Cross Specie & Miscellaneous<br>Animal Research |
| 3 - Rural Dwellings  | 8 - Cotton and Cottonseed                           |
| 6 - Forestry (Other than Forest<br>Service)  | 8 - Tobacco   |
| 7 - Beef Cattle  | 9 - Grain and Forage Crops                          |
| 7 - Dairy  | 10 - Citrus & Subtropical Fruit                     |
| 7 - Poultry  | 10 - Deciduous Fruit & Tree Nut                     |
| 7 - Sheep and Wool   | 10 - Potato   |
| 7 - Swine  | 10 - Vegetable                                      |
|  | 10 - Florist, Nursery & Shade Tree                  |
|  | 11 - Oilseed and Peanut                             |
|  | 11 - Sugar  |

A copy of any of the reports may be requested from Roy Magruder, Office of Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

## INTRODUCTION

This report deals with research on citrus and subtropical fruits such as orange, grapefruit, lemon, avocado, mango, papaya, lychee and dates. It does not include extensive cross commodity work, much of it basic in character, which contributes to the solution of problems of other commodities, as well as those of citrus and subtropical fruits. The progress on cross commodity work is found in the organizational unit reports of the several research divisions of the Department.

This report is organized by problem areas which are shown as the major subjects under the three main divisions in the table of contents. For each of the problem areas there is a statement of (1) the Problem, (2) USDA PROGRAM, (3) REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS for the past year, and (4) PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH.

Research on citrus and subtropical fruit is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the research agencies of the USDA, and (3) private funds for research carried on in private laboratories or for support of State Station or USDA work.

### Research by USDA

Farm Research is conducted by the Crops, Entomology, and Agricultural Engineering Divisions of the Agricultural Research Service. It comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insect control and crop harvesting and handling operations and equipment. In fiscal year 1963, the work involved about 58 Federal professional man-years.

Nutrition, Consumer and Industrial Use Research is conducted by the Human Nutrition, Consumer and Food Economics, and the Southern and Western Utilization Research and Development Divisions of ARS. Nutrition and consumer use pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions; the nutritional appraisal of diets and food supplies; and surveys of the kinds, amounts and costs of foods consumed by different population groups and the practices of families in the purchase and household use of various foods. Utilization research and development deals with methods of preservation through canning, drying, freezing, or combinations of these methods, and also with the origination of new forms of food products or combinations of citrus and subtropical fruits with other foods. In fiscal year 1963, the work involved about 43 Federal professional man-years.

Marketing and Economic Research is conducted by the Agricultural Marketing Service, Economic Research Service, Farmers Cooperative Service and the Statistical Reporting Service. The physical, biological and economic

## INTRODUCTION (Cont.)

aspects of assembly, packaging, transporting, storing, and distribution from the time the product leaves the farm until it reaches the ultimate consumer are investigated by the Market Quality and Transportation and Facility Divisions of AMS. Economic research is concerned with merchandising and promotion; economics of transportation, economics of product quality; market structure, practices and competition; information, outlook and rural development; marketing costs, margins and efficiency; market potentials; supply, demand and price; outlook and situation; improving marketing of farmer cooperatives; and consumer preference and quality discrimination. It is carried on by the Marketing Economics and Economic and Statistical Analysis Divisions of ERS, the Marketing Division of FCS and the Standards and Research Division of SRS. In fiscal year 1963, the work involved about 25 Federal professional man-years.

### Interrelationships Among Department, State and Private Research

Much of the Department's research is cooperative with State Experiment Stations, various sectors of industry and with growers. Cooperative work is jointly planned and frequently participated in by Federal, State and industry workers. The nature of the cooperation varies with each study. It is developed to fully utilize the personnel and other resources of the cooperators. There is regular exchange of information between State and Department scientists to assure that the research programs complement each other and eliminate undesirable duplication. Many Department employees are located at State Stations and use laboratories and office space close to, or furnished by, the State.

Privately supported research of considerable extent is done by food processors and distributors, food industry and trade associations, food container and equipment suppliers, marketing equipment and facility manufacturers, chemical and fertilizer companies, package and container manufacturers, market research institutes and corporations, nurserymen, orchardists, and grove owners. Industry's cooperation in supporting research on citrus and subtropical fruits in the form of grants, gifts or loans of materials, equipment and facilities at Federal and State stations has contributed greatly to its success.

A number of food processing companies and wholesale and retail distributors are presently conducting research in various phases of products and process development in frozen, canned, and dried citrus and subtropical fruit products. The canning, freezing and dehydrating industries each maintain an association with a technical staff and either do research in their own laboratories or support research at USDA laboratories, universities, and other organizations. Allied industries and suppliers to the food processing industry maintain excellent laboratories and large research staffs to provide technical information to the industry.

## INTRODUCTION (Cont.)

Marketing equipment and facility manufacturers also make sizeable contributions to research on the development of equipment for handling fruits on the farm or orchard, into and out of packing houses, transportation vehicle, wholesale distribution center and in the retail establishment, as well as research on the containers in which it is moved and on the transportation vehicles from which it moves from one point in the distribution channel to another. Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, market promotion and development, and interregional and inter-market competition

Chemical and fertilizer companies are significant factors in research on the development of new materials or combinations of materials to produce more efficiently, high quality fruits through better nutrition of the growing plant, control of diseases, insects, nematodes, weeds and the regulation of growth processes through use of growth regulator substances such as fruit set thinners, stop-drop chemicals, bloom retarders, etc.

A number of the larger nurserymen spend considerable time and money in the search for, and testing of, new varieties of citrus and subtropical fruits in the major production areas; sometimes on their own acreage, but usually in cooperation with some grower. The contribution of growers to our overall research effort on citrus and subtropical fruits is substantial. Certainly, in the field of production his help is indispensable for most of the laboratory research results must finally be confirmed by orchard scale experiments. The grower cooperates with the USDA, State Experiment Stations and suppliers of many materials and equipment--usually, without compensation except for the experience and knowledge gained. Citrus growers in Arizona, California, Florida and Texas are conducting research in such areas as flat land reclamation, cultural practices, fertilization, tree spacing, hedging, rootstock evaluation, clonal studies, and are actively cooperating the Department and State Experiment Stations by propagating and testing seedlings, crosses and new varieties.

### Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

Increasing Citrus Fruit Production by Nematode Control. Citrus trees in Arizona are often infected by the citrus root nematode, which never kills the trees, but damages the roots sufficiently to cause decline in growth and reduction in number and size of fruit. No practical control was known until the results of a series of experiments became available. It was found that the nematodes could be killed by applying a chemical known as DBCP (1,2-dibromo-3-chloropropane) in irrigation water. Other chemicals known to kill nematodes also kill the plant roots or are much too expensive for use in citrus groves.

## INTRODUCTION (Cont.)

With the nematodes killed, the root system becomes normal and improved growth and increased fruit production follow. In one experiment with grapefruit, yields were 103 pounds of fruit per treated tree and only 37 pounds per untreated tree. Treated trees produced more and larger fruit. This work is a pilot experiment pointing the way to possible control of other nematodes on citrus and of nematodes in other fruit orchards and vineyards.

Attractants, baits, and sterilants for fruit fly control. Fruit flies constitute the most important insect threats to our tropical fruit industries. Research in Hawaii and Mexico has led to major advances in methods for controlling or eradicating these pests. Several outstanding lures, including methyl eugenol, trimedlure and cue-lure, have been developed which attract males of the oriental, Mediterranean and melon flies. They are of vital importance in early detection of infestations and can be useful in control. In addition, work on attractants for baits has led to the protein hydrolysate-malathion bait spray which was used for eradicating the Mediterranean fruit fly in Florida in 1957 and again in 1962. The eradication of the oriental fruit fly on the island of Rota in the South Pacific was accomplished in 1963 by luring the male flies to a specific attractant, methyl eugenol, containing a small amount of the insecticide naled that killed them. This was the first demonstration of the principle of insect eradication by male annihilation. In the same year the melon fly was eradicated on Rota by reducing the wild flies to low numbers with a malathion-protein hydrolysate bait and then exposing the remaining population to mass releases of male flies sterilized by gamma radiation. This research demonstrated the practical value of the sterility method as applied to an insect population already depleted by the use of a toxic bait.

Mechanization of Harvesting and Farm Handling. In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of dates.

Containerization of Overseas Shipments of Agricultural Perishables.

The containerized shipment of 36,000 pounds of fresh grapefruit in a new type of refrigerated trailer from Lakeland, Florida, to Basel, Switzerland, in November 1962, demonstrated the potential of this form of integrated transport and handling for overseas shipments of United States agricultural perishables. The Swiss receiver and other European fruit importers were so impressed with the superior quality and excellent condition of the fruit in the containerized shipment that they promptly placed orders for additional shipments by this method. Inspection of American fruit

## INTRODUCTION (Cont.)

in European markets and interviews with European importers revealed that losses from damage, pilferage and spoilage on imports of U. S. fruit transported by conventional means ran as high as 50 percent. All importers interviewed stated that they would import more American perishables if they could be delivered with less damage and spoilage.

## I FARM RESEARCH

CITRUS AND SUBTROPICAL FRUIT CULTURE, BREEDING AND  
GENETICS, DISEASES AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem. Citrus has assumed a place of prominence in the health and diet of the American public. To maintain this position, more information is needed on the factors which influence successful and economic production. More precise information is needed on the interrelation between climatic factors and growth, cold hardiness and production; on the absorption processes and functions of various elements needed in growth and the effects of soil salinity, alkalinity and high water retention on growth; on various diseases and methods to control them. New rootstocks are needed which induce more cold hardiness in tops, are disease and nematode tolerant, tolerant to high soil alkalinity, salinity, poor drainage and which induce high yield of high quality fruit. New top varieties are needed with greater cold hardiness, greater disease resistance, better fruit quality, a widespread in season of maturity, suitable both for fresh market and processing.

## USDA PROGRAM

The Department is continuing long-term research program involving plant pathologists, physiologists, horticulturists and plant breeders carrying on both basic and applied studies to enable growers to increase both production and quality. Crosses are made at Orlando, Florida and Indio, California, but not at Weslaco, Texas, and progenies are evaluated at all three locations; disease studies are carried on at all three federal stations; basic physiology studies of cold hardiness are centered at Weslaco, with variety and hybrid progenies evaluated for cold hardiness at all three stations; rootstock evaluation on a field basis is centered in Florida but preliminary evaluation of hybrid rootstock progenies and certain species for cold hardiness, salt tolerance, and disease resistance is carried on at all three stations; basic nutrition is carried on principally in Florida but some work is also done in Texas and California. Climatology is carried on in Florida, Texas, Arizona and in several locations in California; the work in Arizona and California is in cooperation with the agricultural experiment stations. Air pollution studies are carried on in California under contract with the University of California at Riverside.

Four 5-year PL 480 projects are currently in effect: (1) with the Instituto Biologica, Salo Paulo, Brazil, for studies on interference between strains of the tristeza virus (S3-CR-2) providing funds with an \$85,156 equivalent of Brazilian cruzieros and having a projected duration from 1961 to 1966; (2) with the Israel Ministry of Agriculture for studies on the physiological basis of tolerance of

evergreen fruit trees to lime and saline soil and water conditions with special reference to the selection of rootstocks of avocado and citrus by physiological tests (A10-CR-7) providing funds with a \$118,772 equivalent of Israeli pounds and having a projected duration from 1960 to 1965; (3) with the Israel Ministry of Agriculture, Rehovot, Israel for studies of new methods for assessing nutrient status in citrus trees and other plants (A10-CR-36) providing funds with a \$68,900 equivalent in Israeli pounds and having a projected duration from 1963 to 1968; and (4) with the Indian Agricultural Research Institute, New Delhi, for studies on citrus dieback in India providing funds with a \$107,432 equivalent in Indian rupees and having a projected duration from 1961 to 1966.

The Federal scientific effort devoted to research in this area totals 17.9 man-years. Of this number, 2.5 is devoted to breeding, 5.8 to diseases, 0.4 to variety evaluation, 7.7 to culture, 1.0 crop introduction and evaluation, and 0.5 to program leadership.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### A. Crop Introduction and Evaluation

1. Citrus. At Miami, evaluations of avocado introductions have shown that the 'Arue,' P.I. 99805 (Tahiti), and 'Capac,' P.I. 53895 (Ecuador) are consistently early ripeners as compared to commercial Florida varieties. Seedling populations of these varieties are now in field blocks for observation for earliness combined with heavy bearing and quality. These latter characters are lacking in 'Arue' and 'Capac.'

2. Lychee. Cold hardiness and selection of heavy-bearing varieties of lychee are objectives of testing seedling populations at Miami, Fla. Some 1,200 seedlings, marcotts, and grafts were transplanted to the field and were subjected to severely low temperatures this winter. A low of 31<sup>0</sup>F resulted in cold injury that ranged from minor to extensive leaf and wood killing. Mulching studies initiated this year involving the additional effect of applications of sulphur have shown no immediate treatment effects on seedling growth.

3. Subtropical Fruits. Preliminary evaluation of seedling progenies of subtropical fruits such as Papaya, Malpighia, Myrciaria, and Passiflora show that there is considerable merit to the screening of seedling populations to develop varieties superior in adaptation to those introduced directly from the tropics. A yellow-fruited form of Passiflora (Passion Fruit) has proven resistant to fusarium wilt. Research on fruit set of Passiflora has shown that several factors of incompatibility cause failure of fruit set as some cross combinations result in high fruit set while others produce no results.

## B. Breeding

1. Citrus. Hybridization and selection of scion and rootstock varieties was continued with the following objectives: 24 crosses of mandarin types for the production of attractive fruits of high quality with a wide range of ripening season; 9 crosses for production of early orange of high quality plus cold hardiness; 5 crosses for production of cold hardy grapefruit; and 31 crosses for production of salt-tolerant, disease-resistant, dwarfing, cold-hardy rootstocks. In Florida, 52 crosses were made, designed to produce new and less seedy mandarin types and early high-quality, cold-hardy oranges and grapefruit. Seed from these 1962 crosses in California and Florida were distributed among Weslaco, Orlando and Indio, where they will be grown to fruiting.

Hybrids selected for second testing at Indio were as follows: 4 hybrids of Meyer lemon for cold hardiness tests; 1 Temple x Joppa orange F<sub>1</sub> for use in the early maturing orange breeding program; 8 mandarin types for trial as dessert fruits; 2 red grapefruit hybrids for use in the red grapefruit color and size improvement program.

The trifoliolate orange is more hardy than the mandarins and has been used extensively as a source of cold hardiness in citrus breeding programs. The progeny from C. trifoliata crosses always produced acrid inedible fruit and it was assumed that closely linked genes controlled cold hardiness and the unpleasant taste. In 1961, an edible fruited, open pollinated citradia (trifoliolate x sour orange) seedling was discovered by the Department in California. At Weslaco, year old seedlings of this citradia were exposed to 22 degrees F. for 4 hours along with year old seedlings of Satsuma mandarin and of a lemon hybrid. All of the lemon hybrids were killed whereas most of the citradias and Satsumas were not seriously injured. Propagations of the citradia are now being grown in the field at Weslaco, Indio and Orlando for further tests.

Mature bearing trees of most of the hybrids of Clementine mandarin x Orlando tangelo and Clementine x Minneola tangelo at the Hiawassee farm appeared to have cold hardiness equal to or superior to the Orlando tangelo which sustained much less freeze damage under commercial conditions than any of the sweet orange varieties. In addition, large trees of hybrids of Temple x Kinnow mandarin, Temple x Willowleaf mandarin, Clementine x Kinnow, Clementine x Seminole, and Clementine x Kara mandarin growing near Orlando showed greater cold resistance than sweet orange varieties. The cold hardiness of these hybrids apparently derived from the mandarin parentage amounts to approximately 2 to 3 degrees of freeze protection which is roughly

equal to that provided by standard orchard heaters. These mandarin hybrids under Florida conditions generally ripen in October and November and have high quality. These characteristics, combined with cold hardiness, make them worthy of extensive field trial. These hybrids are now being propagated on various rootstocks for further field test.

A study of a population of zygotic seedlings of the Persian lime indicates that ovules and pollen are only occasionally formed in this citrus type. In a population of 250 seedlings, two were apparently nucellar limes whereas the others (zygotic) showed a wide range of characteristics that indicated the hybrid nature of the Persian lime and suggest that the probable parents of the Persian lime were a seedy lime and either a lemon or a citron. Several seedlings resemble grapefruit with a lime flavor and others have orange characteristics. One of the orange types produced nearly seedless, very smooth, rather loose skinned fruits that ripened in August. A cytological study of these zygotic seedlings was initiated.

Widespread freezes during the past winter killed many small seedlings of new hybrids growing at Foundation Farm in Florida, Rio Farms in Texas and Brock Ranches in California. Many hybrids which, as mature trees, are hardy may be fairly sensitive to cold as small seedlings. New hybrid material will be given greater freeze protection during the first two years before transplanting to the field. Foundation Farm, Rio Farms, and Brock Ranges are moderately cold locations and are satisfactory for field screening of new hybrid material for cold hardiness provided trees can be grown for 2 or 3 years before they are subjected to freeze conditions.

2. Dates. In the long term date breeding project, third backcrosses of Khadrawy and Thoory varieties were made in 1962.

## C. Diseases

### 1. Citrus

a. Virus diseases. Tristeza disease continues to spread in Florida, particularly in Orange and Lake counties, despite a state citrus budwood certification system to control it. The disease continues to be distributed mainly through infected nursery tree distribution rather than by insect vectors. The feasibility of maintaining tristeza-free scion blocks is currently moot.

Tristeza tests of unbudded seedlings and of hybrid clones introduced from California and of clones and varieties of special interest were carried out in the greenhouse preparatory to the moving of material to the Foundation Farm. At Chinsegut Hill, Florida, field tests of tristeza strain effects on 25-year old sweet orange trees on sour orange rootstock showed that within two and a half years, the severe strain had caused stunting and leaf drop, whereas the mild and strong strains have had relatively little visible effects on infected trees. Research to study tristeza virus strains in relation to stem pitting is sponsored in Brazil by the United States under provisions of PL 480 Project S3-CR-2 entitled Studies on interference between strains of the tristeza virus. During 1961-62, appropriate citrus understocks and scions, as well as tristeza strains, have been assembled and some inoculations have been made. Results of such studies are not yet available.

The reported seed transmission of xyloporosis was studied during 1956-1962. Infected seeds from 23 sources, 15 known to be infected with xyloporosis (sour orange, Rough lemon, grapefruit, sweet orange, Orlando tangelo, sweet lime, Clementine mandarin, and Rusk citrange) and 8 sources suspected of xyloporosis infection (sour orange, Rough lemon, and Villa franca lemon) were grown in the greenhouse. More than 1800 plants were budded with xyloporosis-free Orlando tangelo and set in the field in February 1957. All trees were examined in 1959, 1961, and 1962, but no symptoms of xyloporosis were found on the Orlando tangelo although in all previous experiments to transmit xyloporosis, symptoms occurred in all inoculated plants within 5 years from budding. Seed transmission of xyloporosis virus, reported by other researchers, has not been demonstrated in systematic tests with experimentally large plant populations.

Reputedly xyloporosis is a sweet lime and cachexia an Orlando tangelo virus disease. During 1959-60, various tangelo and sweet lime varieties were cross-inoculated by budding to determine if the two diseases were caused by the same virus. Reaction during 1962 to the inoculations of the varieties tested suggest that xyloporosis of sweet lime and cachexia of Orlando tangelo are caused by the same virus.

In California, a 5-year study of the nature and extent of stubborn disease showed commercial old-line trees of Marsh grapefruit to be similarly infected when compared with known diseased clones. There was great variability in the performance of infected clones; slight symptomatology was manifest by a high percent of marketable and few abnormal fruit, whereas strong symptomatology was manifest by fewer marketable and many more abnormal fruit.

The successful mechanical transmission of citrus variegation virus to citrus and to cowpea has made possible the determination of such properties of the virus as aging in vitro, tolerance to dilution, and thermal inactivation.

b. Fungus diseases. For the first time, a range of pathogenicity from slight to severe tree damage was demonstrated for Florida cultures of Phytophthora parasitica variously isolated from foot-rot lesions, roots, and soil. Pathogenicity was independent of culture source.

Combining a polyethylene sticker with tribasic copper sulfate or captan fungicides sprayed on tree bases enhanced the tenacity and prolonged the effectiveness of the protectant fungicides. The search continues for improved prophylactic and therapeutic fungicides against Phytophthora root and foot rots.

c. Citrus diseases of undetermined cause. An organism tentatively identified as being in the Physoderma-urophlyctus group of the Chytridiales has been found almost universally present in trees of citrus, certain citrus hybrids, and citrus relatives in Florida as well as in citrus specimens from California, Australia, and Africa. It has been impossible to culture this obligate parasite on artificial media since the organism is carried internally in the seed and all aseptically germinated seedlings were infected. Preliminary experiments to stop or retard growth of the organism in seedlings by treating peeled seeds with fungistatic compounds were unsuccessful. This organism was discovered through histological studies of blight-affected trees but has been found in many trees without blight symptoms.

Robinson tangerine and a number of unnamed hybrids have exhibited severe stem gumming and dieback at various stages of growth. Various facultative parasites such as Alternaria, Diplodia, Phomopsis, Fusarium, and Colletotrichum have been isolated from the infected plants but to date inoculations with these organisms singly and together have not resulted in production of the dieback or gumming symptoms on Robinson tangerine. Attempts to transmit the gumming by grafting are now under way and isolations are being made from infected tissues to discover other organisms which may contribute to these disorders.

d. Biological control of citrus nematodes. Studies on the mechanism of tolerance of citrus rootstocks to spreading decline have revealed that decline symptoms developed in nematode-infected susceptible hosts can be overcome by grafting a nematode-tolerant root system onto the tap root of the infected original host. This indicates that effects of the disease are not irreversible, an important factor to be considered in the rejuvenation of groves by chemical or cultural practices.

Studies using varieties susceptible and resistant to attack by the burrowing nematode indicate that marked stem blockage occurs in nematode-infected susceptible plants but not in nematode-tolerant infected plants. This suggests that Fusarium or some other vascular pathogen plays a role in the decline syndrome.

Studies on nematode-capturing fungi have revealed that various species of the fungal genus Dactylella have differing reactive thresholds to a morphogenic trap-forming substance produced by living nematodes and that the competition of other soil fungi for substrates exerts as much effect upon the nematode-capturing efficiency of predaceous fungi as do the nematodes themselves. A complete medium has been developed for the nutritional studies of various nematode-capturing fungi and a preference for glucose over sucrose as a carbon source has been established for two species of Dactylella. Marked variation in the ability to spontaneously form traps has been demonstrated in various members of the genus Dactylella.

Studies on the development of Radopholus similis nematodes in okra root tissue callus have now been completed. These callus cultures can be grown in standard size test tubes, require transferring but once a year, and the nematodes are highly infective when inoculated into clean citrus roots growing in soil. This technique presents a practical way of raising large numbers of "clean" burrowing nematodes under controlled conditions in a minimum of laboratory space for use in experimental studies.

#### D. Varietal' evaluation

Varietal evaluation studies are limited to testing varieties and kinds for productivity, quality, pollination requirements, root-stock adaptation, disease resistance, cold hardiness, and other climatic requirements. Because of freezing temperatures in all citrus areas during the winter of 1962-63, citrus varieties were particularly evaluated for their cold hardiness.

In general, mandarin varieties tended to have several degrees more cold hardiness than sweet oranges and grapefruit. Several high quality citrus hybrids with mandarin parentage, such as Orlando tangelo, Murcott Honey orange, and the Robinson, Osceola and Lee mandarin hybrids showed cold hardiness comparable to the tangerines. Lemons were the most sensitive to cold injury in all areas.

These results generally verify those observed previously in Florida following the earlier freeze in January 1962.

## E. Culture

### 1. Citrus

a. Pollination and fruit set. At Orlando, Robinson tangerine was an effective pollinator for Orlando tangelo but tended to promote a heavy set of seedy fruit of that variety. At Indio, heavy fruit set required at least 4 leaves and several flowers per shoot.

b. Rootstocks. A new series of rootstock tests employing virus-free nucellar scion varieties has been established in Florida and Texas during the last 5 years and all earlier tests using old-line scion varieties have been abandoned. Although the 1962-63 winter freeze precluded analysis of tests within the freeze area, one test outside of the freeze area in Florida indicated important differences in tree size attributable to the variety of sweet orange rootstock; outstanding varieties to induce vigor were Del Rio, Maltese tangerine, Ross Seedless, and Harvard #2, whereas the sweet orange rootstocks inducing the least vigor in scion varieties were Pope Summer, Parson Brown, Norris, and Athens Late.

All nematode-tolerant rootstock plantings were severely damaged by the mid-winter freeze of 1962 and although most stocks survived, many scion varieties will have to be rebudded. Rootstock seedlings of the burrowing nematode Clone X variety were particularly sensitive to cold.

The selection of 100 outstanding individual seedlings of California Carrizo citrange has been completed and these plants will be used as budwood sources. Also a number of tristeza-free, heat-treated plants of Sanguine grosse ronde orange and Pineapple 156 orange will be propagated and used as sources of seed by nurserymen. In the Rio Grande Valley, exocortis-virus-sensitive rootstocks (Rangpur mandarin-lime and Carrizo citrange) and xyloporosis-virus-sensitive rootstock (Columbian sweet lime) were injured to the same degree as virus-free trees on the same rootstocks by the freeze of January 1962. The recovery of trees on virus-sensitive rootstocks was poorer in the presence of the viruses.

Rootstock variety had a pronounced influence on the cold hardiness of the scion variety. In Florida, Texas, and Arizona, all scion varieties on Rough lemon rootstocks were injured more severely than those on sour orange rootstock. In Florida, sour orange and Cleopatra mandarin were equally effective whereas in Arizona and Texas the Cleopatra mandarin induced more hardiness than did sour orange. In the San Joaquin Valley of California, varieties on rootstocks of trifoliate orange were most hardy, those on sour orange and Cleopatra mandarin were intermediate, and those on Rough lemon or Troyer citrange were the least hardy.

c. Mineral nutrition. The use of luxury amounts of phosphate in Florida citrus fertilizer programs has been a traditional practice. A long-term experiment initiated in 1942 to test the value to citrus of phosphate applied to virgin sandy soil was terminated in 1962. During the 20-year study, tree growth and yield on plots receiving no phosphate were similar to those receiving the recommended rates of that fertilizer. Leaf content of phosphorus indicated that citrus was an efficient extractor of that element from soils having otherwise low phosphorus content. Recommendations have been made to the Florida citrus industry to markedly reduce the superfluous application of phosphates to citrus soils.

In nitrogen fertilizer experiments, a most important development was the recognition of sodium toxicity in orange trees that had received sodium nitrate as the sole source of applied nitrogen for several years. Although citrus roots tend to differentially exclude sodium, leaf analyses indicate an annual cumulative increase in leaf sodium to a toxic level of that element. Leaves having toxic sodium content developed tip browning or acropetal spotting and abscised prematurely. This symptomatology differed from sodium toxicity previously encountered in coastal and irrigated areas of Texas and California and in which the effect was one of a combination of sodium and chloride or sulfate ions and in which foliar symptoms are characterized by a yellowing associated with the necrosis. The practice of growers to use sodium nitrate as a nitrogen source to stimulate trees weakened by water damage or nematode injury, is being discouraged as a result of this information.

Trees with adequate nitrogen were more cold hardy than trees that were nitrogen deficient and this information verified similar observations made initially after the 1957 Florida freeze.

d. Tolerance to salinity and boron. At Weslaco, leaf analysis of year-old nucellar Redblush grapefruit trees on various rootstocks indicated a differential exclusion of certain elements from the irrigation water by the rootstocks as follows: boron by C. macrophylla and Iran lemon; chlorides by Rangpur lime, Siamelo, Cleopatra, and Sunki mandarin; sodium by sour orange; and magnesium by Cuban shaddock, Palestine sweet lime and Iran and Gombru lemons. Shekwasha mandarin rootstock caused scion leaves to have low leaf contents of 4 ions: potassium, boron, sodium, and chlorides.

At Indio, to improve screening methods for salt tolerance of potential rootstock seedlings, it was shown that if visual symptoms of injury are depended upon in screening seedlings for tolerance to chloride, the salt level maintained in the soil should be high enough after 6 or 8 weeks of salt treatment to result in an accumulation of over 3 percent chloride in the leaves of all but the most salt tolerant plants. At relatively low salt levels, only the highly sensitive plants can be detected by visual symptoms.

Research to study the physiological basis of tolerance of evergreen fruit trees to lime and saline soil and water conditions is sponsored by the United States in Israel under the provisions of PL 480 Project A10-CR-7. This research has shown that plants will stand more salinity when the salinity level is developed slowly. The greater tolerance is a direct result of fixing the sodium ions in the acid soluble fractions which in turn markedly affect RNA and DNA metabolism. Salinity increases RNA destruction and the transport of the degradation products out of various plant parts toward apical growing centers.

e. Cold hardiness. The winter of 1962-63 was a disastrous one for all citrus fruit areas. Principal fruit damage occurred in Florida, with appreciable damage in California and Arizona. In Texas the crop was harvested before the freeze. Tree damage occurred in Florida, California and Texas. Tree damage was more severe in Florida than in California although comparable minimum temperatures were more prolonged in California than in Florida. The dry windy conditions of the Florida freeze appear to have been more damaging to citrus on high ground than was the radiation-type freezes on similar locations in California. Other important factors contributing to the lack of damage in California were the high degree of tree dormancy associated with the cold night temperatures during the winter and the extensive use of trifoliate orange rootstock.

Research in Texas with grapefruit, lime, and mandarin indicates that dormancy and cold hardiness is related to bound water in the foliage and that analysis of foliar bound water may provide information about the relative cold resistance of citrus clones.

Age was a factor in a tree's ability to withstand the January 1962 freeze in Texas. Trees 3 to 7 years old were most injured and trees 12 to 15 years old the least injured. Trees older than 12 to 15 years tended to be severely injured because of previous 1951 freeze injury.

At Indio, young seedlings in a Phytophthora-tolerance test planting were evaluated for cold hardiness following the 1962-63 mid-winter freeze. Citrus macrophylla and Microcitrus hybrids were most sensitive to cold; Clone X, Rough lemon, pummelo, C. volkameriana and other lemon-like citrus were moderately sensitive, whereas trifoliate orange, most trifoliate hybrids, mandarins, mandarin hybrids, oranges, and Severinia were highly tolerant to cold. These results confirm Texas information about a lack of cold hardiness of Clone X and C. macrophylla. Texas and California information, however, is not in agreement in regard to the cold hardiness of Severinia.

f. Citrus climatology. Phenological stations were maintained at Orlando and Claremont, Florida; Tempe, Arizona; and Indio, Riverside, and Santa Paula, California. The freeze of January 1962 destroyed the test grove at the Monte Alto, Texas station and the station was subsequently moved to the Hoblitzelle Ranch near Mercedes, Texas. Primary climatological interest concerned the analysis of the series of freezes that invaded all of the citrus producing states during the winter of 1962-63.

Studies made of freezes in the Rio Grande Valley during the past 13 years have indicated that the major factor in the development of cold hardiness in citrus is the induction of bud and cambial dormancy. More recently, experiments with controlled temperatures in growth chambers have demonstrated that induction of dormancy and cold hardiness is accomplished by preconditioning the trees with cold nights. This is precisely what normally happens to citrus trees during December and January at Lindsay, California (San Joaquin Valley) and at Phoenix, Arizona (Salt River Valley), but it does not normally happen at Orlando, Florida and Weslaco, Texas (Rio Grande Valley). Air temperatures normally drop to 32°F or lower 35 days during December and January at Phoenix and at Lindsay but only 1 day once every other year at Orlando and Weslaco. The normal mean minimum temperature during December and January is 35° and 33.5°, respectively at Phoenix, 34° and 33.7° at Lindsey, 50.7° and 49.8° at Orlando, and 52.5° and 51.8° at Weslaco.

The preconditioning of citrus trees with cool night temperatures prior to the 1962-63 freezes was normal only at Lindsay. At Phoenix the mean minimum air temperature during December and the early part of January was 5° above normal. At Orlando, the mean minimum air temperature for the six weeks prior to the December 12-14 freeze was 7° below normal and that at Weslaco for six weeks prior to the January 23 freeze was 5° below normal. Under these 1962-63 pre-freeze conditions, buds were dormant at all 4 locations on all citrus varieties with the exception of Navel oranges and lemons at Phoenix. The bark was tight on twigs, limbs and trunk of trees at Orlando, Phoenix, and Lindsay. The bark was slipping on trees at Weslaco.

Another factor which may possibly influence tree dormancy is soil temperature. The mean soil temperature during the 1962 winter period at the one-foot level was 42° at Lindsay, 45° at Phoenix, 60° at Orlando, and 65° at Weslaco. At these temperatures the roots were showing no growth at Lindsay and Phoenix and were showing slight growth at Orlando and Weslaco.

The Florida, Texas, Arizona, and California freezes all resulted from an invasion of cold dry arctic air but the freeze in each area had its own individuality. The freeze in Florida lasted 2 days, in Texas 3 days, in Arizona it occurred on 8 consecutive nights, and in California it came in waves, the first occurring December 26-31, the second wave January 5-7, the third January 12-18 and the fourth January 20-26. Although the cold air masses entered the areas accompanied by wind, this wind persisted during the freeze at night only in Florida. The air was generally calm during the freeze nights in Texas, Arizona, and California, and radiation freezes resulted. There was no difference in temperature of high and low ground and at levels between 6 feet and 40 feet from the ground in Florida on the first night; but in the other locations, low ground was colder than high ground and temperatures at 40 feet were from 2 to 10 degrees warmer than those at 6 feet. On the coldest night, temperatures were below  $24^{\circ}$  and  $20^{\circ}$ , 8 and 4 hours, respectively, at Orlando, 3 and 0 hours at Weslaco, 5 and 2 hours at Phoenix, and 14 and 11 hours at Lindsay. Temperatures at Lindsay dropped below  $20^{\circ}$  for a total of 38 hours during the 24-day freeze period.

Within the freeze areas there were locations where the climate was several degrees warmer than that described for Orlando, Weslaco, Phoenix, and Lindsay. In Florida, warmer locations included the Indian River section, Highland County, and local areas south of large lakes. In the Rio Grande Valley, Mission was warmer than Weslaco and Monte Alto was colder. In Arizona minimum temperatures varied considerably within the various locations. In the San Joaquin Valley, Orange Cove, and numerous other locations, were warmer than Lindsay. Other citrus areas in California, including the Coachella Valley and the Los Angeles Basin, generally had temperatures higher than those recorded at Lindsay. Temperatures similar to those at Lindsay occurred in eastern San Bernardino County, where a relatively small acreage of citrus is growing.

In Florida and Texas, heaters were used in only a very small percentage of the groves. Heaters and wind machines were used for cold protection in about 30 percent of the total citrus acreage of the Salt River Valley and in about 20 percent of the citrus acreage in the San Joaquin Valley. Where heaters and wind machines were used, the fruit and young tree losses were greatly minimized.

g. Biochemistry. Malic acid is the main acid in the fruit pulp until the time juice begins to form at which time citric acid develops and reaches a maximum concentration in early fall. Citric acid content gradually decreases by juice dilution and other metabolic changes. Oxalic acid occurs only in the rind and reaches its highest concentration in mid-summer.

Valencia and Pineapple oranges harvested from unheated as compared to heated groves during the December 1962 freeze were characterized by a rapid loss of juice, acids, and vitamin C. Heating the grove delayed deterioration and fruits could be harvested over a longer period.

In sand culture studies, lead inhibited root growth at relatively high concentrations but without influence on shoot or leaf growth, whereas arsenic inhibited growth at low concentration as well as inhibiting citric acid formation in leaves.

## 2. Dates

a. Fruit thinning. In a long-term bunch thinning experiment to determine the relation of crop load to fruit quality, trees were thinned to 40, 60, 80, or 100 percent of the bunches produced. Severity of thinning did not markedly improve fruit size or quality but reduced yields. As in previous years, retention of all bunches was the most profitable practice.

Since dates are hand pollinated, the dilution of viable with dead pollen is a potential method of thinning the fruit at pollination. As in 1961, inflorescences in a young Medjool variety planting pollinated with one to two percent viable pollen as compared with undiluted pollen and hand thinning produced unnecessarily large fruit and reduced total yields.

b. Harvesting. A system of harvesting entire bunches when all of the fruit is ripe and removing fruit from the bunch at the packing house by mechanical shaker made no apparent difference in quality or grades compared with dates harvested by usual hand picking. The mechanical shaker method also markedly decreased the number of dates arbitrarily discarded as field culls by hand pickers.

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Variety evaluation - None

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## NEMATODE CONTROL

### Crops Research Division, ARS

Problem. Plant-parasitic nematodes occur in all soils used for growing of crop plants and attack all kinds of plants grown for food, forage, fiber, feed, or ornamental purposes. It has been long known that severity of attack by certain fungi is greatly increased if nematodes are present; and nematodes have been known to be the vectors of several plant viruses. There is a need for improvements in the methods of controlling nematodes by crop rotations, cultural practices, chemicals and biological methods on citrus and subtropical fruits.

### USDA PROGRAM

The Federal scientific effort devoted to basic and applied research on nematodes is 21.5 professional man-years, of which 3.3 are devoted to applied research at Tempe, Arizona; Orlando, Florida and Weslaco, Texas.

### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

No advantage was found for treatment of the soil with a nematocide before replanting citrus in experiments at Tempe, Arizona. However, experiments there indicate that control of citrus nematodes (Tylenchulus semipenetrans) will probably become necessary several years after replanting. Development of methods for control of citrus nematodes in producing groves continue with good results in experiments at Tempe, Arizona. One experiment with grapefruit started in 1858 included applications of 2, 4 and 6 gallons per acre of the nematocide DBCP (1, 2-dibromo-3-chloropropane) and control has been effective for about proportional periods of time. The plots treated with 2 gallons had to be treated again after two years, those treated with 4 gallons after 4 years, and those treated with 6 gallons will need to be retreated soon. Treatment of producing citrus groves with DBCP has become a standard practice in Arizona. Yields have been increased by as much as 23% with increased fruit size, increasing the value of the crop by \$426.00 per acre with a treatment costing about \$15.00 per acre per year.

Active spread of citrus nematode (Tylenchulus semipenetrans) was found to be less than one inch per month in experiments at Orlando, Florida. After infection by the nematodes, Fusarium invaded the citrus roots, but there was no evidence of relationship between the nematodes and infection of the roots by Pythium, Phytophthora or Thelaviopsis.

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## INSECT CONTROL

### Entomology Research Div., ARS

Problem. Efficient production of citrus and subtropical fruits depends upon the availability of effective measures for combatting the many insects and mites that attack these crops. There is a constant need for research to improve present control methods and to secure the necessary information to provide a sound biological basis for their effective development and application. Additional research is needed on biological control agents, including parasites, predators, and diseases; on the integration of biological and chemical control measures; and on safer, more effective, and more economical insecticides to minimize or avoid objectionable residues and hazards to fish and wildlife. Attractants, chemosterilants and other growth-affecting materials and the sterile-male technique are among new or revised approaches to control that need to be investigated. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research to insure the availability of effective, low-cost detection methods, insect control treatments that can be used to permit movement of commodities under plant quarantine regulations, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

### USDA PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. The program is carried on at Beltsville, Md., Honolulu, Hilo, and Kahului, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research Division; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura; on the islands of Guam and Rota in cooperation with the U. S. Navy and Trust Territory of the Pacific Islands.

The Federal scientific effort devoted to research in this area totals 31.5 professional man-years. Of this number 5.8 is devoted to basic biology, physiology and nutrition; 3.6 to insecticidal control; 1.0 to insecticide residue determinations; 3.4 to biological control; 9.7 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.3 to program leadership.

Additional research (4 professional man-years) is in progress under a grant of P.L. 480 funds to the Plant Protection Department of the Arab

Republic, Dokki, Egypt, for studies of induced sterility in males of the Mediterranean fruit fly, Ceratitidis capitata, as a means of controlling and eradicating this pest. In addition, a portion of a grant of P.L. 480 funds (10 professional man-years) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan, is applicable to insects affecting citrus fruits and to tropical and subtropical fruit fly problems in the United States.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### A. Basic Biology, Physiology and Nutrition

1. Citrus Insects and Mites. Surveys revealed the presence of a rust mite, Aculus pelekassi, first found in the United States in 1961 at Orlando, Fla., in citrus nurseries and groves in 13 counties of Florida. The species feeds on fruit and immature citrus leaves, causing distortion of leaf tissue and brown spots on the lower leaf surface. High populations have been maintained on Murcott honey orange seedlings for ten months in an air-conditioned greenhouse; in groves it does not appear to be able to compete on equal terms with the citrus rust mite (Phyllocopttruta oleivora).

Techniques for mass rearing rust mites on citrus in Florida have been developed to a point where adequate numbers are continuously available for evaluating sterilants, antimetabolites, and other chemicals of potential biological activity. Mites are reared on Murcott honey orange or Pineapple orange seedlings in greenhouses maintained between 75 and 85° F. and 50 and 75% R. H. Aculus pelekassi survives conditions of low humidity better than P. oleivora; humidities below 30% inhibited reproduction of the citrus rust mite.

Exploratory work at Riverside, Calif., on the possibility of propagating the citrus red mite on an artificial medium revealed that the mites would feed through certain moisture-proof membranes or gelatinous substrates, such as collodion, cleaners plastic, Du Pont 100 polyethylene and Du Pont 195 MSD-54 cellophane, coated with nitrocellulose; however, it will be necessary to develop a suitable method of confining the mites to the membrane before intensive studies of nutritional requirements for extended rearing can be made.

Little information is available as to the rate of movement and other dispersal habits of the citrus red mite on citrus trees. Isolation and production of an albino strain of this mite provided a tool for obtaining such information. In a preliminary experiment conducted in California in November, movement was slow and restricted. Following release of several hundred of the albino mites on a Valencia orange tree, the mites had moved after 1 and 4 weeks only 6 and 24 inches, respectively, from the original point of introduction. It is expected that the rate of dispersal might be greater in warmer weather.

Periodical surveys of 30 citrus groves in the Rio Grande Valley, Texas, revealed that brown soft scale infestations remained generally light throughout 1962 and until a veritable explosion of the scale population occurred in May 1963. Concurrently there was a decided drop in parasitization of the scale. This coincided with the cotton treatment program but it has not yet been determined definitely that drift of insecticides to the citrus orchards was the cause of the scale outbreak.

In Florida the life histories of Micromus posticus and M. subanticus, important predators of citrus aphids, were similar under laboratory conditions. They required 15 to 16 days for larvae to become adults.

2. Subtropical Fruit Flies. In Hawaii, further developments of mass-rearing techniques for tropical fruit flies have reduced the labor required for handling mature larvae and pupae. A cement mixer blends vermiculite with mature larvae and a mechanical sifter is later used to separate the vermiculite from the pupae. Nine million Mediterranean fruit flies, 26 million oriental fruit flies, and 336 million melon flies were produced this past season. Most of the melon flies were used in a sterile male release eradication test on an island in the Western Pacific.

In Hawaii, populations of the oriental fruit fly, Mediterranean fruit fly and melon fly remained at about the same levels as in last 5 years. In the Mariana Islands, wet and dry seasons cause monthly populations of the oriental fruit fly and melon fly to fluctuate by as much as 70 times with sharp increases during the rainy seasons.

Under caged conditions 100 virgin females of the melon fly confined with a single male produced about 1/6 as many hatchable eggs as the same number with 100 males. Normal females punctured 82% of the cucumbers placed in cages and produced larval infestations in 63%. In a comparable test with an equal number of sterile females, only 40% of the cucumbers were punctured. Under field conditions, wild melon flies laid eggs in 44% of 354 punctures they made in 129 cucumbers, indicating that not all stinging is accompanied by egg deposition.

In laboratory studies with 3-day-old medfly females in copula with males of the same age immotile sperm were present in the spermathecae of 11 of 12 dissected. Four of the flies contained motile sperm in the tubes. Of 25 females from the same lot not observed in copula, 5 had mated. Only 1 of the 37 medflies contained any eggs approaching maturity. These data indicate that the male medfly can reach sexual maturity in 3 days.

Dissections in Hawaii of 20 medfly females caught by trimedlure in Florida showed that the females had fully developed eggs in them but they contained no sperm. A similar response of the sexually mature females to the synthetic male lure in the absence of wild males has been noticed for females of the oriental fruit fly and the melon fly. When catches in male lure traps are predominately female, the male population is extremely low.

In Mexico, tepa-sterilized males competing with irradiated males (5 kr) for a single virgin female were the more aggressive. The number of matings by the tepa-sterilized males exceeded those of irradiated males by a ratio of about 3 to 2. There was no difference in the number of matings between tepa-sterilized males and untreated males. These tests were conducted in the laboratory over a 6-week period and the males were replaced every 3 to 4 days. Recaptured tepa-sterilized males were similar to captured native males in mating aggressiveness.

An effective technique has been developed for the identification of recaptured Mexican fruit flies. Flies that emerge in vermiculite containing a fluorescent dye-petrolatum-stearic acid mixture are marked on the ptillinum and other parts of the body. Dyed flies are easily detected under ultraviolet light after being immersed in fermenting or protein-borax lures for 10 days.

## B. Insecticidal Control

1. Citrus Insects and Mites. In laboratory studies at Orlando, Fla., undertaken to determine some of the factors influencing the effectiveness of acaricides for control of the citrus rust mite, 4- to 5-day-old adult mites were more susceptible to zineb than younger mites. Ethion gave higher mortality on mature than on immature leaves of Murcott honey orange seedlings and was more effective in controlling citrus rust mites on Key lime, sour orange, and Columbia sweet lemon seedlings than on Temple, Jaffa, and Florida sweet orange seedlings. In most tests, mortality of the mites was higher on the upper surface of leaves than on the lower surface.

In the Orlando laboratory 10 p.p.m. of zineb gave complete mortality of citrus rust mites during the summer of 1962, but by early fall there was a marked decline in the mortality resulting from a comparable amount. In recent experiments 50 or 100 p.p.m. of zineb have given less than 50% mortality of mites. Experiments with various formulations of zineb using different sources of water and acetone, different populations of mites (from laboratory colonies and from field collections), and variations in humidity, light, or temperature have been unsuccessful in determining the reason for these changes in effectiveness of zineb against citrus rust mites in the laboratory.

In replicated single-tree field plots at Orlando, Fla., zineb has given good control of citrus rust mites when applied at 1 lb. of 75% WP per 100 gallons of water, but only fair control when used at 1/2 lb. per 100 gallons.

In a comparative test on oranges in Florida Indopol H-100 and Niagara 9102 gave fair control of citrus rust mites for about 9 weeks, while Chemagro 36205, Stauffer R-1504, Kelthane, and binapacryl (NIA 9044) gave control for only 3-6 weeks. Texas citrus mite populations were controlled by R-1504, Indopol H-100, and Kelthane. Plots treated with NIA-9102 had

higher populations of Texas citrus mites than were found on untreated trees. Fruit on trees sprayed with Indopol H-100 had dark green splotches for 4 months after treatment. In another test on oranges zineb and Dithane M-45 were about equally effective against the citrus rust mite and superior to DuPont 328, Shell 3562 and 7438, Nabac 25, and NIA-9203. In still another replicated field test, Stauffer R-1504 was as effective as ethion plus oil and slightly more effective than zineb, ethion, or chlorobenzilate in control of the citrus rust mite; also, zineb and ethion were superior to Bayer 36205, NIA-9102, and Hooker 16A. Stauffer R-1504 and ethion alone or with oil gave almost complete control of the Texas citrus mite. Trees treated with zineb, Hooker 16A, NIA-9102, or chlorobenzilate had higher Texas citrus mite populations than untreated trees.

Because of resistance to the new acaricides, the citrus red mite continues to be the most important pest of citrus in California. Strains of mites resistant to demeton and ovex have been reared in the laboratory without further exposure to chemicals since 1958. After 60 generations, the resistance of the demeton strain appeared to be leveling off at about 35 times the tolerance of a susceptible strain and the ovex-resistant strain at about 60 times. Following an accidental exposure to carbophenothion, the resistance index of each strain increased to 117 and 123 times, respectively. After 28 and 19 additional generations, the indexes of the two strains decreased to 23 and 91 times, respectively. These studies indicated that a significant degree of resistance to certain chemicals may be retained for many generations and that a high degree of resistance may be regained rapidly upon further exposure to chemicals.

In laboratory screening of new chemicals against California red scale, Bayer 45,432 and American Cyanamid CL 43,064 continued to compare favorably with parathion and were considered worthy of field evaluation. In preliminary laboratory tests, Monsanto CP 40,273 and Bayer 45,556 also compared favorably with parathion.

California red scales sprayed with Shell SD 3562 were characterized by abnormal cover development in the immature stages and shedding of covers from many of the mature stages. Counts made two months after the spray application showed 43% of the scales on the fruit and 18% on the wood with covers missing or abnormal. The number of such scales in adjacent parathion plots was negligible. SD 3562 was more effective than parathion against scales on the fruit and was about equal against those on the wood. As in an earlier tree-reaction experiment, there was no plant injury from these sprays.

Laboratory studies were conducted from 1958 to 1962 to determine whether resistance to parathion could be induced in California red scale by selection pressure. Of 30 generations reared, 20 were sprayed with LD 50 dosages of parathion and the strain perpetuated from survivors. A slight rise in tolerance occurred following the early sprays, but there was no further increase. This indicates that the gene for resistance to parathion

is absent or rare in this species. No evidence of red scale resistance has been detected in citrus groves sprayed with parathion for 10 to 12 years.

Dimethoate, 1 pint per 100 gallons, damaged leaves of small citrus trees in a greenhouse as well as those of several varieties of orange, lemon and lime seedlings. In the field in Florida, at both 1/2 and 1 pint per 100 gallons, this material burned new growth in the spring and caused leaf and fruit droppage from sour orange and some rough lemon varieties of citrus trees and failed to control snow scale. Good control of snow scale was obtained with ethion plus oil.

### C. Insecticide Residue Determinations

1. Subtropical Fruit Flies. At Honolulu, Hawaii, ethylene dibromide and ethylene chlorobromide residues were determined in packaged sweet peppers of Yolo Wonder or California Wonder varieties to supplement mortality data obtained with these fumigants. Similar determinations were made for papayas, oranges and other tropical fruits and vegetables.

2. Analytical Equipment. At Hoboken, N. J., the Davis halide meter gave rapid analyses during fumigation of up to 7 oz. of ethylene dibromide per 1000 cu. ft. and to 14 oz. or more with use of a sample dilution technique. In further studies, the thermal conductivity apparatus (Fumescope) is proving to be as useful with ethylene oxide-freon mixtures, as it is with carboxide. A method was developed for doubling the range of the T/C apparatus for determining amounts of carboxide or methyl bromide in high dosage fumigations. This technique utilizes a "Y" with identical sampling tubes of equal length with one tube opening to the open air to give 1-1 sampling dilution. Chemical gas detector tubes (Kitagawa, of Japanese manufacture) appeared excellent for use on low concentrations, including those near the safety threshold of methyl bromide. A similar type tube (Mine Safety Appliance Co.) also appeared promising for either methyl bromide or ethylene dibromide. The Kitagawa detector tubes can be used in areas where the use of flame-type detectors would be hazardous.

### D. Biological Control

1. Citrus Insects and Mites. Determination of the role of parasites, predators, and diseases in the control of citrus insects and mites and studies to improve their usefulness by the introduction of additional beneficial species or through development of integrated control programs are major activities of the research being conducted at Lake Alfred, Fla., in cooperation with the Florida Experiment Station, and at Orlando, Fla. In a 4-year comparison, sulfur spray and dust programs promoted heavier scale populations than programs of zineb alone or with oil. Zineb gave inadequate control of citrus rust mite but with oil added provided good scale and spider mite control. Populations of Agistemus spp., a common predator, were affected severely by sulfur applications but not by zineb

alone or with oil. In periodic surveys of 27 Florida groves through the fall of 1962, 9 of which were unsprayed, 9 treated with sulfur and 9 treated with materials other than sulfur, the heaviest scale populations were found in sulfur-treated groves. Parasites were active in sulfur-treated groves but not enough so to prevent increases in scale infestations.

Introduction of the mite predator Ablydromella rickeri into Florida from California resulted in 1 recovery from 14 releases in 1962 and in 4 recoveries from 5 releases made in 1963. This species feeds and reproduces well on the citrus rust mite. At the same time predators of eriophyid mites are being tested on other hosts than citrus against the citrus rust mite. Unfortunately, Typhlodromus pyri, which feeds on the apple rust mite in Canada, and Typhlodromella rhenana, collected from broad-leaved shrubs in California, have not been able to maintain themselves on citrus rust mites.

The primary purple scale parasite (Aphytis lepidosaphes) and Florida red scale parasite (Aphytis holoxanthus) successfully survived the freeze of 1962. A. holoxanthus, introduced in 1960, appears to be replacing Pseudhomalopoda prima as the dominant red scale parasite in Florida. Chaff scale parasites appeared to be severely affected by the freeze and heavier than normal populations of the chaff scale are expected to develop.

There has long been some doubt concerning the value of Manatee snails as predators of scale insects and mites in Florida. In the course of studies initiated in 1960 and concluded in 1963, no significant differences were noted in scale insect or mite populations on trees with and without snails.

In Florida, zineb reduced the effectiveness of natural control of Texas citrus mites in tests in 3 orange groves. Populations of Texas citrus mites decreased on untreated trees during the three-week period following treatment, whereas there was either only a slight decline or an increase in population on trees sprayed with zineb. Similar results were obtained using NIA-9102 and DuPont 328.

Studies of a viruslike disease of the citrus red mite continued to occupy the major portion of the work program in California. Results of field plot experiments in which the pathogen has been applied to control this mite are still inconclusive. Special studies suggest that higher infection rates of the disease results from the introduction of still active diseased mites than when the pathogen is applied in a spray and when mite populations are high than when they are low. Characteristic birefringent crystals associated with diseased mites occurred in only about 1% of the field mites sampled from known diseased populations when the mites were mounted immediately for examination. This low initial frequency of crystals renders observations for their presence of little value as a method for rapidly detecting the disease in field surveys. When the mites were cultured before examination, however, a significant increase in the number

of mites showing crystals occurred after 4 days, or about 1 or more days before symptoms were readily apparent. The disease crystals are highly variable in their stability. In some amounts made in Hoyer's medium, crystals disappeared entirely within 5 months; in others there has been little apparent change in over 2 years.

Bioassays to determine the effect of insecticide drift from cotton fields into citrus groves in Texas failed to show differences in scale and parasite populations following 8 airplane applications to cotton at 4 to 5 day intervals of methyl parathion at 0.5 pound per acre prior to June 12 and methyl parathion plus DDT and endrin in subsequent applications. However, drift into citrus groves results from such applications, the extent varying with air conditions and method of application. In 1962 air samples showed the presence of as much as 112  $\mu\text{g}$  of methyl parathion/ $\text{m}^3$  air over a 2-hour sampling period starting 1 hour after the end of spraying. High volume air samples showed 0.003  $\mu\text{g}/\text{m}^3$  2 to 3 hours after spraying. Drift residues of 5  $\mu\text{g}/\text{sq. ft.}$  were recorded at distances up to 1056 feet from cotton, at a wind speed of 12 m.p.h. Data from 1963 tests are not complete but spray residues have been recorded at distances up to 1300 feet downwind from sprayed cotton.

Introductions and releases were made in Texas of 5 parasite species from Israel and 1 from California against the brown soft scale. None of these have become established, possibly because of unfavorable conditions during time of release.

In Pakistan, under P.L. 480 Project A17-ENT-5, an intensive survey for scales, fruit flies and mites and their natural enemies was carried out in four zones divided in accordance with topography, climate and host plants. The many species collected and reared are now being evaluated to provide a basic list for more intensive study to determine what, if any, beneficial species are worthy of colonization in the United States. Of particular interest is the recording of 19 species of predators of mites, 10 of which were previously unknown in Pakistan. Some of these predators may be worthy of importation for colonization in the United States. Identification of many of the species collected has been a problem but is gradually being accomplished. There is also under study seasonal fluctuations of the subtropical fruit flies Dacus dorsalis, D. zonatus, and D. cucurbitae and climatic factors affecting their distribution.

#### E. Insect Sterility, Attractants and Other New Approaches to Control

1. Fruit Flies. The first successful use of the male annihilation method has eradicated the entire oriental fruit fly population in a pilot test on the Pacific Island of Rota. This island, 33 square miles in area, is located 37 miles north of Guam. It was an ideal test site because of its isolation. A strong attractant was used to lure the males to an insecticide that killed them. After all males had been annihilated, reproduction stopped and the species disappeared from the island. The attractant used

was methyl eugenol, which the males eat avidly; the insecticide mixed with it was naled. Two methods were used to distribute the poisoned lure on Rota. Over most of the island cane-fiber board squares saturated with methyl eugenol containing naled were distributed by Navy aircraft. The cane-fiber board pieces were about two and one-fourth inches square by three-eighths of an inch thick. Village areas were treated by suspending from trees 6 and 8-inch pieces of cane-fiber containing the lure-poison mixture. At the beginning of the experiment, the cane-fiber squares were dropped at 3-week intervals and later reduced to 2-week intervals. Fifteen drops were completed from Nov. 1, 1962, to June 25, 1963. The rate of distribution was 125 squares per square mile. The permanent bait stations in village areas were treated once a month with fresh poisoned-lure mixture.

The effect of the treatment on the male oriental fruit flies was spectacular. Traps baited with methyl eugenol to determine the male population indicated an average of 262 male flies for the 2 weeks before treatment started. The first drop reduced catches by 93%. What was left of the male population was drastically reduced after each of the succeeding four drops. Catches indicated a reduction of 99.566% of the male population by the end of one generation or after a period of 5 weeks. After three generations and five drops, reduction in the male population was 99.9996%. Bait trap catches indicated 100% reduction by the tenth drop. The last bait catch of an oriental fruit fly was in mid-April, about  $5\frac{1}{2}$  months and four generations after the start of the experiment.

In another outstandingly successful experiment in area suppression of a population of a serious pest, eradication of the melon fly was achieved on Rota with an integrated chemical control and radiation sterilization program that caused the insect to bring about its own destruction. In this large scale experiment, carried out with the cooperation of the U. S. Navy and the Trust Territory of the Pacific Islands, 4 to 10 million melon flies previously made sterile by exposure to gamma rays were released each week beginning in September 1962 and ending July 4, 1963. A total of 180 million flies were produced in Hawaii and flown to Guam for processing and distribution on Rota. When sterile males--either dropped from aircraft or released from cages on the ground--mated with native flies, the resulting eggs did not hatch, thus reducing the new generation. The repeated and systematic release of sterile males eventually wiped out the flies. Within three weeks the sterile flies "overflowed" the native fly population by a ratio of more than 13 to 1. By early December, overflowing was 50 to 1 and it reached at least 100 to 1 by early January. No melon fly maggots have been recovered from watermelons, cantaloups, pumpkins, cucumbers, or tomatoes since December 26, 1962. Average infestation in the first four months of 1960, 1961, and 1962 ranged from 4.5 larvae per pound in tomatoes to 30 in immature cantaloups. Malathion-protein hydrolyzate bait was used to reduce the numbers of wild melon flies on the most heavily infested farms to a point where strong widespread overflowing with sterile flies could be achieved almost immediately. This effective

integration of biological and chemical control methods shortened the time required to obtain eradication and reduced the cost.

A small-scale area control test conducted in 1963 in a mango grove in northeastern Morelos in Mexico, utilizing 28 bait-chemosterilant feeding stations, also gave outstanding results suggesting a possible new technique for the control of the Mexican fruit fly. These stations were baited with 1% enzymatic hydrolysate of cottonseed and the design of the trap was such that attracted flies were forced to come in contact with a wick moistened with water containing green dye and 0.025% tepa, the latter an effective chemosterilant. Flies taken in glass traps showed that about 50% of those in the small isolated test orchard had visited these feeding stations as indicated by the green dye the flies consumed. The ratio of gravid to non-gravid females captured in the test grove was less than one-third of that in a control grove. Fruit samples picked weekly showed no infestation in the test grove in April compared to 3% infestation in the control grove. Fruit from the test grove remained remarkably free of fruit fly infestation (less than one-half percent infested) throughout May; whereas, more than 60% of the fruit samples from the control grove became infested.

The effectiveness of flooding wild populations of Mexican fruit flies with tepa-sterilized flies was demonstrated again in 1963 in a 10-acre mango grove at El Bebedero, Morelos, Mexico. The first test was made in 1962. About 9 million flies were released in this grove from stations containing puparia that had been treated with a 5% tepa solution. Less than 1% of the fruit harvested through May 21 was infested, whereas 76% of the fruit was infested in check groves a mile or so from the release stations. The flies were sterilized by dipping pupae in a tepa dip. Sterilization was accomplished when the adults became contaminated by tepa residues as they emerged.

In Hawaii, laboratory tests to develop methods of sterilizing fruit flies with chemosterilants also indicated that a tepa solution dip of pupae will be effective for the Hawaiian fruit flies. Emerging melon flies forced to pass between sponges containing 0.5% apholate did not produce eggs; a 1.5% solution gave similar results on the oriental fruit fly. For both species less chemosterilant was needed to cause sterility in the males than in females. Residues of 1:10 apholate or tepa-protein hydrolysate (food attractant) in water spray on foliage was very effective against all three species.

Trimedlure-baited wicks exposed for 9 weeks in December and January in Florida were still as attractive to medfly as freshly-baited wicks when tested in Hawaii. Studies of evaporation rates of trimedlure in Florida showed that effective amounts can be maintained on 3/8" wicks by retreating at intervals of 3 to 4 weeks during the summer and 6 to 9 weeks during the winter and on 3/4" wicks by retreating at intervals of 6 to 9 weeks during the summer and 9 to 12 weeks or longer in the winter.

In Egypt, under P.L. 480 Project F4-ENT-3, research preliminary to field tests of the release of sterile males of the Mediterranean fruit fly to control or eradicate this insect is well underway. The technique for mass-rearing the medfly under Egyptian conditions to provide the numbers of flies needed for such an experiment is receiving major attention. Contamination of the rearing medium with a phorid fly has proved to be an unsuspected problem that must be solved. Meanwhile, a test site has been located and studies to assess the fruit fly population throughout the year are in progress.

#### F. Evaluation of Equipment for Insect Detection and Control

In tests conducted in Hawaii, a trap containing solid trimedlure (57° C. MP isomer) provided performance equal to the standard. With modification of the lure holder to facilitate removal of the trapped insects, this method may prove useful in Mediterranean fruit fly detection programs.

#### G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. The new 24 oz. ethylene dibromide per 1000 cu. ft. fumigation at 50-60° F. was used at Hoboken, N. J., for 120 fumigations of approximately 85,000 cases of Israeli (Jaffa) oranges in large, steel chambers, using axial fan recirculation near two changes per minute. Gas concentrations, distribution, and penetration into fruit boxes with different types of stacking were satisfactory in a series of over 225 analyses, as were the stainless-steel electric stoves used for vaporization of gas. Gas concentrations were far below the maximum acceptable concentration of 25 p.p.m. for personnel safety in warehouses used for holding fumigated fruit. Tolerance of Jaffa oranges to the heavy dosage was satisfactory.

Further tests have been conducted to develop fumigation schedules for infestation of fruit flies in packaged sweet peppers. Ethylene dibromide treatments were phytotoxic at effective levels whereas ethylene chlorobromide caused less injury. Mediterranean fruit fly infestations in packaged oranges required the same dosage of EDB at 60° F. as at 50° F.

2. Ionizing Radiation. In Hawaii the investigation of ionizing radiation for commodity treatments has been continued. No injury was noted when gamma radiation was applied to sweet peppers at 150 kr, eggplant at 50 kr, pineapples at 100 kr, and Haden mango at 200 kr. Adult mango weevils in Haden mango seeds survived 9.15 kr. However, larvae and pupae failed to survive 10 and 50 kr, respectively. Sexually mature and immature weevils were sterilized by 5 kr and 15 kr, respectively.

#### H. Insect Vectors of Diseases

1. Citrus. At Orlando, Florida, continued emphasis was placed on studies to determine factors that influence spread of the tristeza virus by aphids.

Low transmission efficiency has made it difficult to obtain enough data for definitive conclusions. Experiments thus far have failed to substantiate indicated differences between vector efficiency related to sources of virus inoculum. There is increasing evidence that aphids from different sources or strains may vary in their efficiency as vectors. In tests of various possible controlling factors the size of Key lime indicator plants did not influence the rate of transmission. The rate was higher when test plants were held in a screenhouse than when they were held in an air-conditioned greenhouse. The number of aphids used also influenced the rate of transmission. Ten, 25, 50, 100, and 200 melon aphids transmitted tristeza to 5.8, 3.3, 8.4, 10.0, and 14.6% of Key lime indicator plants, respectively. Experimental transmissions have increased appreciably since melon aphids for virus transmission studies have been reared under controlled temperature and humidity conditions.

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CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT  
Agricultural Engineering Research Division, ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research was initiated at Lake Alfred, Florida; and Davis, California; in cooperation with the respective State Experiment Stations. The Federal engineering effort devoted to research in this area totals 30.5 professional man-years, of which 4.0 is on citrus.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Harvesting Citrus. Over \$50,000,000 are paid to workers who pick the crop by hand. Increased citrus production together with a shortage of suitable labor has created a need for improved methods and equipment for harvesting citrus fruit. AERD initiated research in cooperation with the University of Florida and the Florida Citrus Commission on October 1, 1962, at Lake Alfred, Florida, and in cooperation with the University of California, January 1, 1963, at Davis, California. In Florida fruit removal tests were conducted with a six-inch stroke inertia tree shaker, in the same plots of early season oranges in which the four-inch stroke shaker was used last season. The severe freeze of December 13 prevented any further fruit removal study this season. A fruit catching frame and frame-mounted inertia shaker were built and tested under various grove conditions. The catching-frame is equipped with conveyor and elevator to handle fruit in 10-box metal baskets. A picking platform mounting three pickers and employing the pick-and-drop principle (made by Mr. Boyer, Tampa, Florida) was tested in sparse fruit and half-dead Valencia trees. Pickers averaged only 17 boxes per hour compared to 20 boxes per hour by conventional picking with ladders.

In California one phase of the project objectives are to determine characteristic physical properties of the tree and its fruit and to utilize these properties to mechanically harvest the fruit. Preliminary tests performed on navel oranges indicate the following: (1) More than 75 percent of fruits detached with a pull applied in line with the stem were removed without stem

or calyx, and (2) fruits detached by spinning were removed with or without stem and calyx depending on the orientation of the spin axis with the fruit core axis. Limited studies of the electrical and thermal properties of the tree components and fruit indicate no apparent application of these properties to mechanical harvesting.

Harvesting Dates. Dates grow on palm trees which are 30-60 feet high and it is becoming difficult to find workers to pick fruit by hand in these tall trees. During 1962 experimental fruit removal equipment and complete harvesting systems were designed and tested to determine the feasibility of bunch harvesting. Two vertical vibrators were designed and built which removed dates from the bunch mechanically. They deliver a 3 1/4-inch stroke to the bunch at 600-1,100 cycles per minute. One hundred percent removal was accomplished in about two seconds. Two men operating one vibrator can shake 450 bunches per hour. The two harvesting systems were as follows: One system features straight down-the-row operation of the "date tower" allowing all mature bunches to be harvested from two opposite palms at each stop. Fruit is removed from the bunch, by a vibrator, directly into bulk bins as the tower progresses down the row. The second system uses a smaller tower which allows harvesting 1/2 a palm per stop. Harvested bunches are hauled in trailers to a central location for shaking. Time studies of the two harvesting systems combined with other studies have shown: (1) Bunch harvesting is feasible, and (2) both harvesting systems will reduce total harvest costs relative to the hand-picking method. Harvest rates of 0.96 acres per hour (46 palms per hour) were attained where an average of one-half of the bunches on each palm were mature. The results were so promising that the experimental equipment was used commercially in harvesting 1 1/2 million pounds of dates. Also bulk boxes were used successfully for the first time in handling dates.

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## II NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

### UTILIZATION RESEARCH AND DEVELOPMENT

Western Utilization Research and Development Div., ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from almost all of the navel oranges, contains unknown substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing; and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

### USDA PROGRAM

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California; at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California; at the University of Hawaii, Honolulu; and, under a P.L. 480 grant, in Bogota, Colombia. Investigations are conducted on the composition of citrus essential oils, flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, enzyme systems that are involved in the appearance and disappearance of constituents and structures of plant tissues, constituents of dates that affect the quality and stability

of products, and the application of findings of such research to the development of new and improved citrus, tropical, and subtropical fruit products.

The Federal program of research in this area totals 18.0 professional man-years, including 3 scientists whose salaries are provided by two cooperators under Memoranda of Understanding (Lemon Products Technical Committee - 2, and the Date Administrative Committee - 1). Of the total 13.6 are assigned to investigations on chemical composition and physical properties; and 4.4 on new and improved food products and processing technology. In addition, the Division supervises a research project on development of new tropical fruit products supported by a P.L. 480 grant.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### A. Chemical Composition and Physical Properties

1. Citrus Composition. The chemical composition and physical properties of citrus fruits determine the quality and stability of products made from them. Research is underway on the composition of cold-pressed lemon oil and lemon juice concentrate, the two principal lemon products in domestic and international markets, supported in part by the Lemon Products Technical Committee which pays the salaries of two research fellows at the Pasadena Laboratory. There are two problem areas. The first is concerned with differences between lemon juice and essential oil as they exist in the fruit and as they exist in products prepared for sale. These differences arise from the processes used in their manufacture and from handling the products in distribution. The second is the identification of components of lemon products over a wide range of growing areas to guide processors in improvement of processing methods. This information is also useful to lemon growers and processors to verify authenticity of lemon products in the market as a protection against unscrupulous competitors who market spurious products under the guise of authenticity, in violation of pure food laws. In both areas the approach has been to determine the composition of lemons and lemon products and to study the relationships of components to quality and to deteriorative changes that occur in the processing and subsequent handling of preserved products.

The terpenes (10-carbon hydrocarbon components) of lemon essential oil have been well characterized in earlier research and attention has been directed in the past year to the sesquiterpenes (15-carbon hydrocarbons). The principal sesquiterpenes of lemon oil have been isolated and the two most important (beta-bisabolene and bergamotene) identified. They have a mild odor and exist in sufficient quantity to add notes to lemon flavor. These two compounds make up about half of the sesquiterpene fraction, which is nearly 2% of whole lemon oil.

Studies of the carotenoids of lemon juice were initiated and 22 of these components, which are related to the color and nutritional qualities of lemon products, were revealed as natural components. These include

substantial amounts of phytofluene, zeta-carotene, and cryptoxanthin. Studies will continue on the further identification of carotenoids and will be extended to the steroid components.

Total amino acids, malic acid, total polyphenolic compounds, and titratable acidity were determined over a wide range of lemon juice samples known to be authentic. Limits of variability were established for several of these components to compare with analyses of lemon juice or concentrate of unknown purity. Characterization of individual amino acids will be continued. Methods for determining total carotenoids and steroids have recently been developed and are being tested.

2. Bitter Constituents of Citrus. Several classes of compounds that are natural constituents of oranges and grapefruit impart color and flavor to food products. During processing and in subsequent handling and storage, changes occur that affect the quality of the products. Clear understandings of the flavonoids in citrus and the quality contributions of various flavonoid compounds are a first step toward improvement of products and processes. Several flavonoids of citrus and citrus products have been identified and their contribution to flavor and color deterioration of preserved products has been determined. As reported in last year's report, naringin and neohesperidin are bitter constituents of the grapefruit and the bitter orange. There are also tasteless flavonoids in citrus. The flavonoids consist of a polyphenolic base connected to a compound sugar molecule. The bitter flavanones can be converted enzymatically to eliminate bitterness by separating the sugar from the base. They can also be debittered by another chemical reaction which has been accomplished in the test tube, converting the base to its equivalent dihydrochalcone. The bitter characteristic is related to a chemical linkage within the compound sugar molecule. Bitter flavonoids, when converted to the dihydrochalcone become very sweet. Tasteless flavonoids do not become sweet when converted to the dihydrochalcone.

A related flavonoid compound, phlorin, has a simple sugar rather than a disaccharide attached to the polyphenolic base. It is present in many citrus products and can participate in a browning reaction in the presence of amino acids which are also present in all citrus.

In these studies, new polyphenolic compounds were isolated and identified, including vitexin, in which the sugar is linked to the polyphenolic base by a carbon-to-carbon bond rather than carbon-to-oxygen-to-carbon linkage. Identification of these compounds and determination of their molecular structure involved analyses of components and degradation products, and synthesis of related compounds from precursors of known configuration.

Studies of limonoid compounds in citrus have been initiated. One, limonin, is an interesting, bitter compound found generally in citrus seeds and also found in the fruit of navel oranges, a seedless sport. Navel oranges

constitute a major part of new western plantings for the past several years. Attempts have been made to find an enzyme that will specifically change limonin to a tasteless compound. The only success in this work so far is with enzyme preparations that also settle the suspended material in the juice. Other methods of fragmenting limonin in order to debitter navel orange juice are under investigation.

The structural configurations of other highly oxygenated terpenoid bitter principles of citrus are also being studied in continuing research.

3. Fruit Flavor Components. Gas-liquid chromatography has rapidly advanced the chemistry of volatile components in a few years. Dual columns with dual-flame ionization detectors and programmed temperature control achieve remarkable sensitivity. The combination of gas-liquid chromatography with time-of-flight mass spectrometer separates and identifies substances in fractions of a part per million including materials whose separate existences are transitory. For the first time a class of flavor compounds called acetals have been detected in fruit volatiles. Some of the acetals have significant aromas and may contribute important flavor notes to fruits and fruit products.

Refinements in separation and detection of volatile components do not eliminate need for large-scale extraction to recover workable amounts of substances that exist in parts per million concentration in the original fruit. Identifications of some classes of flavor constituents continues to defy existing gas-liquid chromatography and other ultramicro methods. A solvent-extraction facility is nearing completion at Albany, California, that will allow for extraction with low flash-point solvents on a sufficiently large scale to make identifications not heretofore possible. The components of orange and other citrus juices will soon be studied on the same scale as investigations of commercially prepared cold pressed orange oil and other materials which have been obtained in large quantity under commercial operating conditions. Extractions will be made with these new facilities with much more knowledge of raw material than was ever possible from commercial samples.

Subjective evaluations of flavor are being made on purified organic compounds from food volatiles and believed to be related to flavor. A trained taste panel determines odor thresholds of aqueous solutions. This is one phase of a systematic approach to provide necessary correlations between the chemistry of volatile compounds and the flavor of foods. In order to study the effect of mixed systems, several compounds have been assembled in sub-threshold concentrations and evaluated together. From preliminary studies it appears that there is an additive relationship between chemical components in olfactory response. Thus, the aroma threshold of a ten-component mixture was identified by a test panel when each of the components existed at one-tenth of its individual threshold concentration. This finding is an early step toward interpretation in terms of flavor of the complicated chromatograms obtained in advanced chemical studies.

4. Composition of Dates. Utilization research is conducted with industry support by means of a fellowship salary provided by the Date Administrative Committee operating under a Federal Marketing Order. Objectives of the research are to study the natural components of dates, evaluate their relationships to quality of dates and date products, and to apply new information to the improvement of products and processes (see also paragraph B-2, Improved Date Products). Basic research, reported earlier, revealed compositional changes in dates that could be induced by naturally-occurring or added enzyme systems. Empirical studies guided by the research led to a commercial operation wherein dates were so treated that natural enzymes hydrolyzed sucrose to glucose and fructose and improved the flavor and texture. There appears to be more involved in this process than the simple inversion of sucrose, and further studies have been undertaken to elucidate other chemical actions involved in order to control commercial operations more positively.

Color deterioration of dates is now known to follow three pathways: (1) enzymic darkening, (2) oxidative browning, and (3) non-oxidative browning. Polyphenolic compounds that enter into the enzymic darkening of dates are being investigated. A caffeoylshikimic acid has been crystallized from date extracts and demonstrated to be a new enzymic browning substrate. This provides an important lead in the elucidation of date darkening. In order to obtain a more concentrated source of date flavonoids for chemical identifications, the date leaves were examined. Date leaves were found to have a high content of rutin, a compound with pharmaceutical properties. Because date cultural practices in this country are responsible for a large accumulation of leaves as a waste product, the presence of important components in leaves may offer another source of financial return for the grower. Investigations of date leaf components will continue along with the compositional studies of the dates.

5. Desert Grapefruit. Compositional studies on desert grapefruit and grapefruit products were recently initiated. Much work has been done on the composition of oranges and lemons in recent years using new methods of analysis and instrumentation. No equivalent compositional information has been obtained for grapefruit. A few scattered analyses are available on fruit of unknown cultural history, but most of these data were obtained using older methods of analysis, some of which are now considered inaccurate. Personnel have been assigned to this research and some routine analyses on minerals and vitamins will be handled by purchase contract. Separation and characterization of selected components of grapefruit will be carried out with emphasis being placed initially on sesquiterpenes, organic acids, carotenoids, sterols, and flavonoids.

6. Pharmacological Research. Caloric availability assays have determined the metabolic fate of citrus pectin ingested by rats receiving a restricted caloric intake. Pectin digestibility was low and, on the basis of weight gains, the small amount of pectin which was digested was not well utilized

as a source of energy for growth. Published findings outside the Department indicate that pectin included in the diet of rats at a rate of 5% will counteract the deposition of cholesterol and lipids in the liver which is induced by dietary cholesterol. The rats used in the pharmacological studies at Albany, California have been sacrificed and blood serum and liver samples have been frozen for later determination of cholesterol. The possibility that ingested pectin may inhibit the absorption of dietary or endogenous cholesterol from the digestive tract should be of interest to all concerned with blood cholesterol levels.

## B. New and Improved Food Products and Processing Technology

1. Citrus Products. An important problem of the citrus industry is control of excessive bitterness in some products such as grapefruit and navel orange juice. There appear to be two major groups of compounds responsible for bitterness in citrus. These are the flavanone glycosides which cause the bitterness of grapefruit and Seville oranges and the limonoid compounds, a group of complex terpenoid substances that cause bitterness in navel orange products and in citrus seeds. As basic compositional research is conducted on these compounds, the new knowledge obtained is continuously applied in laboratory studies aimed at overcoming the flavor defects. Because the chemical structure of naringin, the bitter substance of grapefruit, has been elucidated it was possible to devise two ways to control this bitterness in laboratory tests. Enzymatic alteration of naringin by breaking the glucosidic link to form a non-bitter compound in grapefruit juice was accomplished in the laboratory but is not yet developed into commercial process. The slow reaction does not fit into large volume handling of the modern fruit juice plant. This bitter flavanone was converted to its equivalent dihydrochalcone in the laboratory. The new dihydrochalcone is intensely sweet, approximately 20 times as sweet as common synthetic sweeteners. Preliminary pharmacological tests indicate this new substance to be a safe food product. Several companies are now investigating the commercial applicability of this new product as a low calorie sweetener for foods. The market for low calorie sweeteners is currently about 4 million pounds per year and expected to expand to about 10 million pounds by 1970. The market now is being supplied by synthetic sweeteners produced from non-agricultural raw materials.

The debittering of navel orange juice by enzymic conversion of limonin is also being studied. No enzyme has yet been found that can make the chemical conversion without deleterious side effects such as clarification of the juice. Research directed toward finding a method for control of orange bitterness will be continued.

Knowledge of lemon juice composition is proving useful for determining purity of lemon juice products. In addition to their natural desirable flavors, lemon juice and concentrates contain large amounts of citric acid and are bought and sold on this basis for many food uses. Citric acid content is the most widely used measure of concentration of the juice. The lemon juice

producers were seeking a more exacting procedure to guarantee the authenticity of their product. Four quick, easy laboratory tests were used to establish a multiple correlation based on lemon juice of known purity. A formol titration for total amino acids, a polarimetric determination of L-malic acid, and a spectrophotometric estimation of the total polyphenolics were correlated statistically with titratable acidity, calculated as citric acid. The results of these tests were linked by computer, and limits were set to judge quality of unknown products in trade channels. The equation developed can describe authentic lemon juice by measurement of natural components that cannot be easily confounded by addition of inexpensive chemicals. An adulteration of as little as one-fifth of the natural citric acid content can be reliably detected. So small an addition would not reduce cost of product to a point where illegality is reasonably attractive. As a further refinement, measurements have been made on the individual amino acids, total carotenoids, and steroids of lemon juice. Preliminary results indicate that these substances are in proportion to citric acid. Their measurement may improve tests of lemon juice purity.

2. Date Products. As reported earlier, dates of softer texture and sweeter can be produced from hard and lightly flavored dates by treatment under conditions that accelerate the action of the enzyme invertase. Department studies leading to this new process were partially supported by industry funds. The process requires no new packing house equipment and has overcome a long standing problem of the domestic date industry. Normally about half of the United States crop fails to ripen to top quality and lacks soft, smooth texture. The new process involves heat activation of the natural date enzymes that convert sugar in dates to invert sugar. The conversion increases tenderness, improves flavor, and decreases the tendency of dates to dry out during storage. The proportion of dates harvested that will need to be processed by this improved method is increasing because of mechanical harvesting, in which all the dates on a particular tree are harvested at one time, precluding some of the natural ripening. The treated dates maintain their softness at low moisture levels and are especially suitable to new date and cereal products such as breakfast foods and baking mixes. Solution of the date texture problem has broadened domestic markets and places United States dates in a stronger competitive position for world markets.

3. Tropical Fruit Products. Agriculture in the new State of Hawaii has had severe economic problems. Caught between increased labor, package material, and freight costs on the one hand and foreign competition for traditional food markets on the other, it needs improved processing and new products to lower costs and improve quality so that the tropical and subtropical conditions in that State may be an adequate source of agricultural income. A new field station within the Western Utilization Research and Development Division has been established in Honolulu where cooperative research will be conducted with the Hawaii Agricultural Experiment Station. This research program will be focused on bulk and weight reduction of tropical fruits to yield high-quality, stable products for export to the

mainland or foreign countries. Improved means for retention or restoration of flavor in tropical fruit products will be investigated.

4. Foam-mat Drying. Laboratory and pilot plant investigations continue on the application of the foam-mat drying process invented by Department engineers at Albany, California. Cooperative research with the Southern Utilization Research Division is being conducted on the foam-mat drying of orange and other citrus products at Winter Haven, Florida. Informal cooperation continues with industry representatives who are interested in commercial application of foam-mat drying. Three commercial-scale configurations now exist. Two have been used for commercial-scale research. One drier has produced commercial lots of foam-mat dried tomato, pure lemon juice, and lime concentrate. Research has been conducted to further reduce the moisture of already foam-mat dried powders to eliminate the necessity for in-package desiccants for extremely hygroscopic materials. Rotating vacuum drying equipment, using lime as a moisture acceptor and an electrically heated outer cylinder has been designed. Orange powder can be reduced from 3-1/2 to 1% moisture by tumbling 2-1/2 to 3 hours at 130° F. A method has been developed to reduce the bulk and improve color of foam-mat dried powders. The powders are run between hot rolls which increase their density and provide for more efficient packaging. Conditions for rolling various products have been developed based on the sensitivity of the products to temperature and density specifications. For example, foam-mat dried orange powder is rolled at temperatures between 130 to 180° F. while tomato powder can be rolled at temperatures as high as 205° F. Orange solids have been prepared with a density of 0.8 grams per cubic centimeter which provides more solid material in a container than is present in a 60% frozen concentrate.

Important flavor components are frequently lost in the juicing, concentrating, and drying operations required to produce foam-mat dried or any other dehydrated fruit product. Methods are under investigation for adding back important flavor components in a stable form. The locking-in of orange oil with various types of sugars as carriers, has been used for sometime for citrus powders and formulated citrus flavored beverage powders. Recent research has provided locked-in orange oil at higher concentrations than previously available--up to 10%. The new equipment reduces the time the oil is in contact with melted sugars at a high temperature which might lead to deterioration of the oil. Work will continue to improve the quality of natural flavors which will be added back to foam-mat dried fruit products.

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## UTILIZATION RESEARCH AND DEVELOPMENT

### Southern Utilization Research and Development Div., ARS

Problem. The citrus and subtropical fruit production of the Southern Region is an expanding industry with the need for the development of better, as well as new-type consumer products, and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits, to the economic advantage of the growers and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils, flavonoids, including bitter constituents, constituents responsible for oxidized off-flavors, carotenoids, and the like, which determine many of the sensory characteristics, and which affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, fermentation, and the like. Increased production of citrus has stimulated the development of new products but many of these are urgently in need of improvement which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change, to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products, and to develop new or improved canned products which have a natural fruit flavor. Research is especially needed on grapefruit to develop practical methods for reducing the bitterness and harshness of juice products and to increase the use of grapefruit juice base in mixed fruit juice blends, drinks, concentrates and the like. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials, to obtain and maintain the most desirable fruit characteristics. As an illustration, research is needed to develop less expensive dehydration equipment and an improved process for the production of citrus powders.

### USDA PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, food technologists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of citrus and subtropical fruits, and their products and byproducts is conducted at the U. S. Fruit and Vegetable Products

Laboratories at Weslaco, Texas and Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food products and processing technology. At the Weslaco Laboratory the program includes investigations of the biochemical mechanism of the conversion of precursors to carotenoids in grapefruit as a basis for improvement of processing characteristics of and products from colored grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR, ARS, Weslaco), and the Texas College of Arts and Industries are providing grapefruit of known history and conducting, or cooperating in conducting, on the tree tests. Additional research on chemical composition and physical properties is carried out under contract at the University of Oklahoma Research Institute, Norman, Oklahoma, on investigations of the effect of maturity of grapefruit on total flavonoids, naringin, and poncirin; and on the chemistry and nature of naringin and naringin-derived compounds to provide a scientific basis for the control of bitterness in processed grapefruit products. At the Winter Haven Laboratory the program includes investigations of the neutral fraction of orange peel extract with the aim of isolating, characterizing, and identifying those substances, particularly bitter principles, that are most detrimental to the flavor of orange products. Investigations are also in progress on the composition of essential citrus oils as related to flavor of juices, concentrates, powdered juice, and other products; on investigations of the chemical and physical nature of components of cloud of orange juice to provide better understanding and control of factors affecting stability of orange juice products; and on investigations of the identities, quantities and chemistry of components in Florida grapefruit responsible for excessive bitterness and harshness in processed products. Close consultation is maintained with the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred) and the industry.

Research to develop new and improved food products is carried out at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas, and Winter Haven, Florida. At the Weslaco Laboratory the major applied effort is to develop products which will make greater and more efficient use of grapefruit. Emphasis at the present time is on the utilization of natural and debittered grapefruit juice and puree as bases for the development of improved fruit juice blends, drinks, and concentrates. This research is being carried out in part in cooperation with several state and private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Formal agreements exist with the Texas Agricultural Experiment Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco) and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Canners Association (Weslaco) and such other organizations as are found necessary for the procurement and processing of fruit. At the Winter Haven Laboratory research is in progress to develop high quality, "instant" citrus powders by new and improved processing technology as described below.

In the field of new and improved processing technology, research is being carried out at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, to determine how the "foam-mat" type of air-drying can be applied for the preparation of dried citrus products of optimum flavor and stability. Foam-mat drying of orange juices, and grapefruit juices, is being studied. This research is conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 20.4 professional man-years. Of this total 12.0 is devoted to chemical composition and physical properties, 3.0 to new and improved food products, and 5.4 to new and improved processing technology. The contract research involves an additional 1.4 man-years, all of the effort being on chemical composition and physical properties.

The following lines of work were terminated during the year: (1) Investigations on preservation of chilled citrus products to prevent spoilage and permit delivery of improved products; and (2) Investigations to develop new and improved processed products from selected minor fruits, with emphasis on avocados, limes and Meyer lemons (under new and improved food products).

#### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Chemical and Physical Properties of Flavoring Constituents of Florida Citrus and Subtropical Fruit Products. Basic work on the composition of essential citrus oils as related to flavor of citrus products was continued. Two new constituents of essential orange oil, delta-3-carene and rhodinal, have been identified. It has been found that during the process of determination of orange oil on silica gel columns isomerization of terpenes results. The possibilities are suggested that d-limonene is the precursor of alpha- and gamma-terpinene, terpinolene and p-cymene in orange oil; and that alpha-pinene is the precursor of camphene. The feasibility of low temperature isomerization of terpenes on silica gel might provide a commercial source for many of these isomeric products. The presence of hexanol, octanol, nonanol, decanol and undecanol in cold-pressed orange oil was firmly established. Two of these alcohols (nonanol and undecanol) are new constituents. Beta-sitosterol was isolated from orange cold-pressed peel oil. Three new terpenes ( $\alpha$ -thujene, sabinene, and camphene), and a sesquiterpenoid having a conjugated ketone, have been isolated from grapefruit oil. The latter compound has the odor characteristic of grapefruit. The products obtained upon isomerization of limonene oxide have been identified as havenal, dihydrocarvone, and 1-acetyl-3-isopropenylcyclopentane. This may serve as a new commercial use for d-limonene. (S3 2-36).

## 2. Investigation of Bitter Principles and Flavonoids in Citrus Products.

To date approximately 79% of the neutral fraction of orange peel juice extract has been accounted for in research on bitterness in oranges. This fraction is the largest and most bitter of those separated from this source. Tentative composition of the neutral fraction is: tangeretin, 4.9%; nobiletin, 35.5%; sinensetin, 24.2%; 3,5,6,7,8,3',4'-heptamethoxyflavone, 6.1%; and unidentified flavone, 8.6%. The structure of sinensetin has been definitely determined to be 3',4',5,6,7-pentamethoxyflavone and not the 3',4',5,6,8 as formerly thought. From the analysis of the neutral fraction it should be possible to determine which substances are responsible for most of its bitterness once the principal constituents are evaluated separately. A monthly examination of orange peel juice during the 1962-63 fruit season indicated a decrease in bitterness as the season progressed. Since the season was unusual due to the December freeze, the results will have to be checked in a normal year. If it can be shown that bitterness decreases late in the season to a point where it is no longer offensive, commercial producers of orange juice could increase their extractor pressures during this time without increasing bitterness in the product. (S3 2-37).

Contract research is being initiated at the University of Oklahoma Research Institute to investigate the changes which occur as grapefruit matures--in total flavonoids, poncirin, naringin, and naringin-derived compounds responsible for bitterness--to provide a scientific basis for the development of control methods and blending procedures in order to process uniformly flavored grapefruit products throughout the processing season. It is planned to study Texas grapefruit, at least in the initial investigations. (S3 2-39 (C)).

## 3. Factors Affecting the Physical Characteristics of Processed Citrus Products.

A stable cloud is considered to be an essential characteristic of high quality orange juice products. In further work on the composition of cloud of orange juice, centrifugally sedimented solids and cloud have been recovered from orange juice at three stages of maturity and classified into three portions according to sedimentation rate. Suspended solids have also been recovered from pulp washings. All of the cloud fractions have been extracted with alcohol, acetone, and ether for the separation of lipids and water-insoluble suspended matter from the soluble solids of the juice. Ash, phosphorus, and nitrogen content of the insoluble solids have been determined. The suspended solids recovered by mild centrifugation (A) were found to have very high pectinesterase activity, while the cloud recovered by the highest available centrifugal force (B and C) showed significantly higher activity on the dry weight basis. Observed differences in composition between the easily sedimented particles (fraction A) and fine cloud (fractions B and C) indicate that at least some of the stable cloud components are not products of mechanical degradation of rag and peel. Fraction A contained more debris from cellular structure, as evidenced by higher cellulosic content, than did fractions B and C. The cloud fractions contained more lipids, and the solvent-insoluble portions of these fractions were

richer in pectin and nitrogen, and slightly higher in ash, than fraction A. The principal effect on the composition of cloud caused by freezing weather was an increase in solvent-insoluble solids for both A and B fractions. The information being developed may have considerable value in assessing effects of processing variables on juice quality. (S3 2-38).

4. Basic Investigations of Carotenoids in Grapefruit. Basic research on carotenoid formation in grapefruit has continued. For further experiments to establish whether carotenoids are made sequentially or by parallel synthesis, a means of purifying zeta carotene and phytofluene has been sought, with no success. However, the study of biosynthetic relationship of carotenes has proceeded, basing results on phytoene, lycopene and  $\beta$ -carotene, which can be adequately purified and account for about 95% of tomato carotenes. Radioisotope studies (incorporation of  $C^{14}O_2$  into carotenoids) with tomatoes (used because of their more rapid synthesis of carotenoids) have provided data which support the postulate of simultaneous synthesis of lycopene and carotene considerably better than of sequential synthesis.

Preliminary results have indicated that the age of fruit seems to contribute slightly more to the seasonal decline of lycopene in colored grapefruit than factors correlated with date. Since most frozen trees had too "sets" of fruit this year, research was initiated to attempt to eliminate the variable of the individual tree by following lycopene content in each set of fruit on the same tree. The analysis of two "sets" of fruit on the same tree has again verified both the effect of age of the fruit and season of the year in producing the maximum lycopene content of red grapefruit. The data obtained this year indicate that season of the year has more influence than was shown last year. Application of  $C^{14}O_2$  to grapefruit on the tree seems to have established that fruit, per se, and possibly carpels and peel, can individually make carotenes from carbon dioxide. When fruit were exposed, the total amount of label in the peel was higher at 48 hours than at 30 days, but label in the carotenoids was greater at the longer time, indicating continuous synthesis and a very slow turnover of carotenoids. When leaves were exposed, the total label in both peel and carpels was greater at 30 days than at 48 hours. Label in the carotenoids followed the same pattern but was much more pronounced again indicating continuous synthesis and a very slow turnover. (S3 2-34; S3 2-34 (Rev.)).

#### B. New and Improved Food Products

1. Improved Chilled and Canned Citrus Products. Good progress was made in continued research on the preservation of chilled citrus products. Heat treatments ( $140^{\circ}$  -  $160^{\circ}$  F.), preservatives (sorbate, benzoate), and a storage temperature of  $30^{\circ}$  F. have been found to effectively increase the shelf life of chilled orange juice. Heat treatment and low storage temperatures reduce initial plate counts, inhibit microbial growth, and retard flavor change. Ascorbic acid in heat-treated, single strength orange juice was slightly more stable than that in unheated juice when the juices were stored at  $0^{\circ}$  F. At  $-90^{\circ}$  F. storage, ascorbic acid was lost more rapidly

in the juice heated to 160° F. than in the unheated controls. Preservatives are beneficial under adverse storage conditions (above 30° F.) in minimizing changes due to microbial growth. Results from cloud determinations were inconclusive, but the trend was toward greater cloud stability with heat treatment. It has been confirmed that vitamin K<sub>5</sub> accelerates the loss of ascorbic acid in chilled orange juice. The vitamin appears to function as an oxygen carrier via a quinone-hydroquinone-type mechanism. This finding makes the use of vitamin K<sub>5</sub> as a preservative in chilled citrus products undesirable. (S3 2-35).

2. Development of New Grapefruit Based Beverages. Exploratory investigations were conducted on the use of debittered grapefruit juice in the preparation of fruit and berry flavored punches and drinks. The enzymatic debittering of grapefruit juice increased its flavor compatibility with such flavors as strawberry and raspberry. Debittering made it possible to increase the quantity of grapefruit juice in the juice blends and drink bases. Highly acceptable drinks were prepared with partially and completely debittered grapefruit juice blended with juice or puree from such fruits and berries as orange, strawberry, raspberry, blackberry, and plum. Taste panel testing has been used to determine preferences for levels of bitterness, acid and sugar in selected grapefruit juice-based drinks. The masking effect upon bitterness in grapefruit based drinks by blackberry puree was confirmed by a taste panel who compared the blackberry flavored drinks with other fruit flavored drinks. Seventy-three percent of the panel said blackberry flavored drinks were less bitter than plum flavored drinks; seventy-nine percent, less bitter than raspberry; eighty-seven percent, less bitter than strawberry; and ninety-three percent, less bitter than naranjilla flavored drinks. Storage studies were initiated on a four-fold (3+1) strawberry flavored grapefruit drink concentrate in plain and enameled cans at storage temperatures of 0° F. (control), 40° F., 50° F., 68° F., and room temperature. Initial results (1 month storage) showed that for the 68° F. and room temperature storage, samples from the enameled cans rated higher in flavor. Samples stored in plain tin showed a greater color loss than samples in enameled cans at storage temperatures of 40° F. and above. The use of resins such as Nylon 66 and Polyclar AT powders to absorb the principal bitter constituent(s) in grapefruit juice appears promising. Experiments demonstrated that these powders will absorb naringin from grapefruit juice without adversely affecting acidity, Brix, or vitamin C content. Trial runs with the powders and bitter grapefruit juice were successful. Both resins can be regenerated for reuse by washing with hot water or by extracting with alcohol. Control of bitterness by this means may have possibilities for industrial application. (S3 2-33; S3 2-40).

### C. New and Improved Processing Technology

1. Application of Foam-mat Drying to Florida Citrus. Storage studies on orange juice powders produced by the "foam-mat" drying process have shown that storage at 85° F. accelerates the production of off flavors, compared to the 0° F. stored controls. Moderate storage life is possible at 70° F.

In investigations of factors affecting processing and product characteristics of foam-mat dried orange juice powder, none of the variables tested could be shown to increase the shelf life of the products in 85° F. storage. The addition of peel oil prior to foam preparation was found to reduce the rate of moisture removal during drying. The addition of SO<sub>2</sub> at 200 ppm in foam preparation did not prove advantageous. Likewise, further tests with nitrogen both in foam preparation and product packaging failed to show any differences in flavor stability between air and nitrogen processing and packaging. Processing of concentrates containing different amounts of pulp has shown that the rate of moisture removal during drying decreased as pulp content increased. Improvements in equipment and refinements of techniques in the foam-mat process have been made, leading to better initial products and confidence in the experimental results. (S3 2-32).

New research has been initiated to investigate foam-mat drying of concentrated grapefruit juices to provide a new grapefruit product of optimum flavor and high stability. The research will be cooperative with the Florida Citrus Commission, Florida Citrus Mutual, and WU. Preliminary experiments only have been conducted which indicate the feasibility of foam-mat drying concentrated grapefruit juices. Next phases of work will consist of investigation of time-temperature variables in the process, and freeze-drying of some concentrate to obtain grapefruit powder samples for comparative evaluation of quality characteristics and for control purposes. (S3 2-41).

#### PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

##### Chemical Composition and Physical Properties

Lime, Bruce J. and Tucker, Donald M. 1962. Seasonal variation in Texas Hamlin and Mars orange juice, 1961-62. J. Rio Grande Valley Hort. Soc. 16, pp. 78-82.

##### New and Improved Food Products

Kew, Theo. J. 1962. Cloud and flavor stability in relation to density of frozen concentrated orange juice. Proc. Florida State Hort. Soc. 75, pp. 342-349.

Kew, Theo. J. and Veldhuis, M. K. 1962. Stability of frozen concentrated citrus juices following adverse storage. Food Technol. 16, pp. 119-122.

Tucker, Donald and Lime, Bruce J. 1962. Production of pulp-fortified concentrate from Ruby Red grapefruit - A progress report. J. Rio Grande Valley Hort. Soc. 16, pp. 112-120.

Veldhuis, M. K. and Kew, Theo J. 1962. Storage time and temperature affect frozen citrus juice quality. ASHRAE (Am. Soc. Heating Refrig. Air-cond. Engrs.) J. 4(12), pp. 43-46.

New and Improved Processing Technology

- Bissett, O. W., Tatum, J. H., Wagner, C. J., Jr., and Veldhuis, M. K. (SURDD); Graham, R. P. and Morgan, A. I., Jr. (WURDD). 1963. Foam-mat dried orange juice. I. Time-temperature drying studies. Food Technol. 17, pp. 210-213.
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General

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NUTRITION AND CONSUMER USE RESEARCH  
Consumer and Food Economics Research Division, ARS  
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help carry out the Department's responsibility to advise on the quantity and variety of foods that will assure maximum benefit and satisfaction to consumers, continuous research is essential on the nutritional requirements of persons of all age groups, and on the nutrient and other inherent values of foods and how to conserve or enhance these values in household preparation and processing. Periodic examinations of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective nutrition education. Such information provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and use.

PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service--the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done at Beltsville, Maryland, and in Hyattsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 66.3 man-years. It is estimated that approximately 2.9 man-years is concerned with studies related to citrus and subtropical fruit products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity

basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 23.4 professional man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to horticultural crops are considered briefly in this report.

## PROGRESS

### A. Nutrient Values of Citrus and Subtropical Fruit

1. Tables of food composition. The 1963 revision of Agricultural Handbook No. 8 "Composition of Foods...Raw, Processed, Prepared" was completed and carried through to the galley proof phase. Data for about 40 citrus and other subtropical fruits are included in the new edition of Handbook 8. For many of these foods sufficient data were available to permit classifying by variety or type, market form--raw, canned, frozen, juice, pulp--or other characteristic. The total number of citrus and subtropical fruit items included in the revised Handbook 8 is approximately 140.

Data in the popular publication, "Nutritive Value of Foods," Home and Garden Bulletin No. 72, have been revised to agree on a weight basis with nutritive values in Handbook No. 8. The revised edition will provide nutritive values of household measures of 512 commonly used foods. Another popular publication, "Conserving the Nutritive Value in Foods," Home and Garden Bulletin No. 90, is in press.

2. Vitamin analyses. Research continued on procedures useful for B-vitamin analyses to permit characterization of B-vitamins in citrus, subtropical fruit, and other foods and to determine their overall distribution in the food supply. A procedure has been developed for the quantitative determination of pyridoxine (vitamin B<sub>6</sub>) as pyridoxal cyanohydrin. Studies will be continued to apply this chemical procedure to the assay of vitamin B<sub>6</sub> in food extracts and to verify results by comparisons with those of the microbiological assay.

An improved method for thiamine determination also has been developed. The conditions of the 6-aminothymol colorimetric reaction were changed so that a stable fluorescent compound was produced with thiamine. The fluorescence made possible measurements at much lower concentrations and appeared to be simpler than the usual thiochrome reaction.

3. Mineral elements. Laboratory analyses for the content and distribution of 10 mineral elements in 29 fresh fruits and 6 dried fruits from different locations are near completion. The mineral element content of several fruits varied from location to location. Data are being summarized for statistical analyses and a technical bulletin will be prepared.

Analyses for total nitrogen and ash are in process on the 29 fresh and 6 dried fruits being analyzed simultaneously for mineral element content.

4. Carbohydrates. Studies were initiated on direct laboratory analyses for the carbohydrate content of foods, usually expressed as a difference value in tabulations of proximate composition. The sugars in 20 fresh fruits, including deciduous fruits and berries, were determined by analyses for total sugars, reducing sugars, sucrose (by difference), and glucose and fructose in the reducing sugars by differential oxidation. The studies are continuing on identification and determination of individual sugars in fruits.

#### B. Properties Related to Quality and Consumer Use of Citrus and Subtropical Fruits

1. Organic acids, carbohydrates, and fruit quality. Research is in progress on the types, amounts, and stability of organic acids and various forms of carbohydrate in fruits before and after freezing. The extent to which these components determine quality, texture, and flavor characteristics of peaches, strawberries, raspberries, and cantaloups is being studied. Physical and chemical determinations include citric, malic and quinic acids, pectins, soluble solids, titratable acidity, pH, sugars (glucose, fructose and sucrose), reflected color and shear force.

The enzymatic preparation, Pectinol 100-D (Rohm and Haas), in the colorimetric carbazole reaction was found to interfere in the determination of pectins. Pectinol 100-D used in the amounts recommended for the determination of protopectin produced an interfering color which caused a 20 percent error in results in fresh peaches. If Pectinol 100-D is used for pectin determination it is recommended that a correction for the interfering color be made. Pectinol R-10 (Rohm and Haas) and Pectinol (K & K Laboratories) produced no interfering color.

2. Storage of dried fruits. Laboratory studies were completed to relate moisture content and quality of uncooked dried fruits of specified types, grades and sizes, that were stored under different conditions, to the quality and yield of the cooked products. A report presenting the results is being written.

3. Food buying guides for school lunch managers. A revision of PA-270, Food Buying Guide for Type A School Lunches, was completed in cooperation with the Agricultural Marketing Service. New data were added to the 1955 edition and the format was changed to make the guide more usable by school lunch managers participating in the National School Lunch Program.

4. Food buying guides for families. Work has been initiated on a food buying guide for family use.

### C. Nutrient Functions

1. Lipids. Research on the effect of feeding rats, throughout their life-time, diets containing fresh and oxidized olive oil was continued under contract in New York City. Structural analyses of triglycerides in the diets and in adipose tissue have shown that rats produced molecular types not present in the dietary fat although the structure of the depot fat was strongly influenced by the dietary fat. Oxidation of the dietary fats exerted only a mild effect on the structure of the depot fat triglycerides.

2. Carbohydrates. Basic research using small animals and microorganisms is contributing to an understanding of the influence of type of carbohydrate on lipid and protein metabolism and to our knowledge of factors influencing the physiological response to carbohydrate containing foods. Protein components in the blood serum of rats, particularly rapidly moving components (PA), varied with diet and with age. PA was present more often and in larger amounts with fasted rats fed a sucrose-containing diet than with rats of comparable age on a starch-containing diet. With either carbohydrate (sucrose or starch), more PA was generally present in the serum of 350-day-old rats than in that of 150-day-old animals. With glucose, PA was present in small amounts in a larger percentage of rats, and no age effect was apparent. The percentage of 150-day-old sucrose-fed rats with serum containing PA was higher in nonfasted than in fasted rats; the reverse was observed with glucose. Lipid material was found in the PA components. The presence and amount of these components may provide an additional means of measuring response to diet and may prove a valuable tool for studying lipid transport.

### D. Requirements for Nutrients

Preadolescent age group. Cooperation has continued with experiment stations in the Southern Region (S-28 revised) for investigation of metabolic patterns and for assessing requirements for and utilization of selected nutrients by preadolescent children. In 1962, at Blacksburg, Virginia, 12 preadolescent girls were maintained on controlled diets with variation in the amount of protein (entirely from plant sources). Citrus fruit juice supplied a considerable portion of the dietary ascorbic acid. The Texas Agricultural Experiment Station determined the average daily ascorbic acid content of the diets, the urinary excretion of the vitamin, and the blood serum levels. Analyses completed for intake and outgo of fat suggest that the amount of fecal fat excreted by the subjects was about twice the amount of fat excreted by subjects on controlled diets in earlier studies, where the protein was mainly from animal sources, although the content of total fat in the diets was comparable.

### E. Food Consumption and Diet Appraisal

1. Food consumption and dietary levels. A report of the findings of the food consumption survey of beneficiaries of Old Age and Survivors Insurance made in Rochester, New York in the spring of 1957 has been completed. The

survey included 283 1- or 2-person households. During the survey week, food brought into the kitchens of these households averaged about the following amounts per person: 4 quarts of whole milk or its equivalent in milk products; 4 pounds of meat, poultry, fish; 1/2 dozen eggs; 10 pounds of vegetables and fruits; 2 pounds of grain products (in terms of flour); 1 pound of sugars and sweets; and 3/4 pound of fats and oils. The total money value of all food per person was \$8.12. Nutrients from this food more than met the National Research Council's recommended allowance for the average person. However, less than half (44 percent) of the households had diets which met in full the recommended amounts for all nine nutrients (good diets). Nearly three-fourths of the households had diets that met two-thirds of the recommendations for all nutrients (good and fair diets). The nutrients which fell below the recommended allowances most often were thiamine and calcium.

The series of food surveys conducted in low-income areas to aid in the study of the effects of food distribution programs on diets of families has been extended to include a survey carried out in Choctaw County, Oklahoma and in Pensacola, Florida. These were conducted cooperatively with the Marketing Economics Division, Economic Research Service as were similar surveys reported previously.

A food consumption survey was carried out in the District of Columbia that will provide information on the diets of households and of individuals. The study was undertaken primarily as a pilot survey in developing procedures for the next Nationwide survey proposed in the Department's long-range program.

The nutrient content of the per capita food supply is calculated and published each year, using data on estimated quantities of foods consumed (retail-weight basis) as developed by the Economic Research Service. This series, with estimates extending back to 1909, is the only source of data on year-to-year changes in the nutrient content of the U. S. per capita food consumption.

2. Food management practices. The results from three small studies based on records kept by the homemaker on the kind, amount, and nutritive value of foods used and discarded in households have been prepared as a journal article. In terms of total calories available for consumption, discarded edible food averaged 7 percent in St. Paul, Minnesota; 3 percent in DeKalb County, Missouri; and 10 percent in Los Angeles, California. A study using "recall questions," instead of records, with a random sample of 300 households in Minneapolis-St. Paul in the winter of 1960 is currently being processed.

A report on household practices in handling and storing commercially frozen foods, based on surveys in two cities has been published. Survey findings indicate that household practices alone would not cause serious quality deterioration of frozen foods.

A new study has been initiated (under contract) of the management practices of urban and farm home freezer owners in Fort Wayne, Indiana, and a nearby rural area. The survey is designed to obtain information on such actual management practices of home freezer owners as the kinds, amounts, sources, prices, and rate of turnover of foods frozen and stored in the home.

3. Development of food budgets and other basic data for food and nutrition programs. The ongoing program of interpretation and application of nutrition research findings to practical problems for use by nutritionists, teachers, health workers, and other leaders concerned with nutrition education or nutrition policies has involved the preparation or review of articles and publications, talks, television interviews, and participation in various conferences and committees.

With the publication of the report "Family Food Plans and Food Costs" the technical work on the development of the Department's current low-cost, moderate-cost and liberal food plans was completed. The continuing phases of the work on individual and household food budgets consists in the regular pricing of the food plans for publication in Family Economics Review, and in dissemination of information concerning them through such popular publications as "Family Food Budgeting for Good Meals and Good Nutrition," through filmstrips (Food for the Young Couple), and through correspondence, talks and committees (such as the Advisory Committee to the Bureau of Labor Statistics on their City Workers' Standard Budget).

Progress on the revision of Handbook No. 16, "Planning Food for Institutions," has focused primarily on the food purchasing guide section. Publications in preparation that are designed for the use of teachers, extension workers and other leaders are (1) a semi-popular publication on nutrition in the series Facts for Nutrition Programs, (2) a report on fat and related components in U.S. diets, and (3) a study of the relative economy of foods.

Nutrition Committee News, a bimonthly periodical prepared for members of State nutrition committees and other workers in nutrition education provides one channel for disseminating pertinent information and for reporting nutrition education activities. Examples of subjects of current interest covered during the report period are: "Nutrition Aspects of Selected Studies of Cardiovascular Diseases--Implications for Nutrition Education," "Planning Nutrition Programs for Elementary School Teachers," and "Food Guides--A Teaching Tool in Nutrition Education."

## PUBLICATIONS

### Nutrient Values

Toepfer, E. W. 1962. Procedure for chromatographic separation and microbiological assay of pyridoxine, pyridoxal, and pyridoxamine in food extracts. Paper given at Committee on Vitamin B<sub>6</sub>, Food and Nutrition Board, NAS-NRC, Denver, Colorado.

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#### Properties Related to Quality and Consumer Use

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Harp, H., and Dunham, D. 1963. Comparative costs to consumers of convenience foods and home-prepared foods. Marketing Research Report No. 609, 91 pages, illus. Human Nutrition Research Division cooperating.

#### Nutrient Functions

Lakshmanan, F. L. 1963. Factors influencing the presence of rapidly migrating serum protein components, PA. Federation Proc. 22(2), Part 1, p. 608 (abstract).

#### Food Consumption and Dietary Levels

Consumer and Food Economics Research Division. 1963. Food consumption and dietary levels of households of different sizes, United States--by region. Household Food Consumption Survey 1955, Rpt. No. 17. 168 pp.

Adelson, S. F., and Keys, A. 1962. The diet and some health characteristics of 123 business and professional men and methods used to obtain the dietary information. ARS 62-11. 280 pp.

#### Nutritive Value of National Food Supply

Consumer and Food Economics Research Division. 1962. Nutrients available from civilian consumption per capita per day 1935-39 and 1947-49 averages, 1960, 1961, and preliminary estimates for 1962, with percentage comparisons. Table 4. Nat. Food Sit. Oct. p. 22.

Consumer and Food Economics Research Division. 1962. Nutritional review. Nat. Food Sit. Oct. pp. 21-25.

### Food Management Practices

Redstrom, R. 1962. Consumer practices in handling and storing of commercially frozen foods. Family Economics Review, ARS 62-5. Sept. pp. 3-7.

### Development of Food Budgets and Other Basic Data for Food and Nutrition Programs

Consumer and Food Economics Research Division. 1962. Estimated cost of 1 week's food. In Family Economics Review, ARS 62-5. (U.S.A. average issued quarterly, estimates for four regions issued annually.)

Consumer and Food Economics Research Division. 1962. Food for the young couple. Home and Garden Bul. 85. 16 pp.

Cofer, E., Grossman, E., and Clark, F. 1962. Family food plans and food costs, for nutritionists and other leaders who develop or use food plans. Home Economics Research Rpt. No. 20. 54 pp.

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## III MARKETING AND ECONOMIC RESEARCH

## MARKET QUALITY

## Market Quality Research Division, AMS

Problem. Research is needed on the measurement of quality in citrus and other subtropical fruits. With a better understanding of quality characteristics and objective indices for the measurement of quality, grades and standards would be more meaningful and could be better enforced. In addition instrumentation for quality measurement lends itself to ultimate automatic devices for quality sorting on a commercial basis. Fruit soilage and wastage resulting from postharvest decays of citrus fruits present serious problems in both domestic and export markets. Much research is needed to relate handling practices, packaging, precooling and transit refrigeration to decay and soilage, and to develop and evaluate physical and chemical treatments for decay reduction. Research is also needed on the storage of citrus fruits. Optimum storage temperatures for the principal varieties of oranges produced in different areas need further investigation. There is also a vast field for research on controlled atmosphere storage for oranges, grapefruit and lemons. Problems exist in each of the geographical areas which are sometimes distinct and sometimes interrelated, but which require biological research in the separate production areas for solution. Several species of common stored-product insects attack dried citrus pulp animal feed and may build up tremendous populations. In some cases wholesalers and retailers have refused to handle the product because the excessive insect infestation creates a hazard to other commodities in stock. There is an urgent need for effective preventive measures to be used in warehouses that will not leave hazardous residues in the feed, and for the development of packaging that will resist insect infestation of the product in marketing channels.

## USDA PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. The work is conducted in the producing areas of California, Florida and Texas. Market studies are made in New York City and Chicago. P.L. 480 grants are operative for research in Columbia on chemical and physiological variables in avocado and papaya fruits during ripening; for studies in India on identification and mode of infection of fungi causing postharvest rots in seven species of tropical fruits; a project in Italy on X-ray detection and identification of incipient decays in citrus fruits; and a recently negotiated contract in Spain on detection of additives

in citrus juices. A study on objective measurement of maturity is conducted, under contract, by the California Agricultural Experiment Station at Riverside. Research on biphenyl for decay control is done in cooperation with the California Citrus Research Committee. Current irradiation research is done in part with funds provided by the Atomic Energy Commission.

Total federal professional man-years devoted to this area is 11.1. Of this 3.0 is devoted to objective measurement of quality; 0.6 to quality maintenance in storage; 2.0 to quality maintenance during transportation; 1.0 to postharvest physiology; 4.0 to postharvest disease control; and 0.5 to program leadership. P.L. 480 projects in this area involve \$64,145 equivalent over a 3-year period in Columbia; \$45,200 equivalent over a 5-year period in Italy; \$29,732 over a 5-year period in India; and \$56,163 equivalent over a 4-year period in Spain.

Work terminated during this period included transit protection of Hawaiian fruits (MQ 2-25); biphenyl resistance of Penicillium sps. (MQ 2-26); transportation of California citrus (MQ 2-27); accumulation of biphenyl in citrus fruits (MQ 2-28); enzyme activity related to maturity of avocados (part of MQ 2-46); and enzyme activity and maturity of avocados (part of MQ 2-60).

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### A. Objective measurement of quality

1. Relation of Physical Properties, Chemical Composition and Metabolic Activity to Market Quality of Citrus. Weight, volume, length, and diameter measurements of Florida-grown Marsh grapefruit showed decreases during storage in each of seven tests. This shrinkage proceeded only slightly more rapidly at 60° than 32° F. Ethylene treatment markedly increased the rate of shrinkage during the treatment period, but the rate in subsequent storage was frequently lower. Seasonal changes, though possibly influenced by the freeze, show an increased amount of shrinkage with increased maturity.

Results of three tests on oranges indicate that the same pattern of response occurred, but the changes were proportionately greater than on grapefruit.

A test with a commercial reflectance sorter indicates that satisfactory sorting of oranges for color can be made by this means.

Basic studies being conducted under contract with the University of California, Riverside, have continued. Data on labeled carbon dioxide fixation and exchange in orange tissues indicate a significant

drop in rate of C<sup>14</sup> O<sub>2</sub> fixation in the vesicles as maturation progresses.

Experiments with specifically labeled glucose showed significant differences between tissues in probable major metabolic pathways. In all tissues carbon 1 of glucose is catabolized more rapidly than either carbon 2 or carbon 6. However, whereas carbon 2 is metabolized more rapidly than carbon 6 in flavedo, the opposite is true in albedo and vesicles. There may be a significant change during maturation in the rate of catabolism of carbons 3 and 4 of glucose relative to other carbons.

2. Aromatic Polynuclear Hydrocarbons in Horticultural Crops. Work is underway at the Pomona, California laboratory to develop methods for removing polynuclear aromatic hydrocarbons from the surface of citrus fruit, for subsequent qualitative and quantitative analysis. The most promising procedure at present for measuring these hydrocarbons is to extract them with n-pentane, separate them by thin layer chromatography, elute the desired portions, and determine absorbence on a U. V. spectrophotometer.

3. Enzyme Activity and Maturity of Avocados. A preliminary study at Beltsville showed no detectable change in pectinmethyl esterase activity that could be associated with maturity of avocados. No further work is planned.

#### B. Quality maintenance in storage

1. Ripening and Storage of Florida Mangos and Avocados. Storage studies on a new and important mango variety, Tommy Atkins, indicate that it has excellent storage characteristics and shelf life. The fruit softened in 3 weeks at 70° F. and no chilling injury was detected after 1 week at 45°. Tommy Atkins is one of the firmest and brightest and most attractive of the commercial varieties; eating quality is only fair.

Studies on a new variety of avocado, Ruehle, indicate that it has typical characteristics of the West Indian strain, particularly in susceptibility to chilling injury at temperatures below 50° F.

#### C. Quality maintenance during transportation

1. Export Shipment of Florida Grapefruit. This work has shown that early season, minimum maturity, Marsh Seedless and Ruby Red grapefruit should be transported at 60° F. to avoid rind breakdown during distribution in European markets. Fifty to 55° F. is a better temperature for the more mature fruit. The simulated export studies conducted this season substantiated the findings of the previous crop year.

Some of the more promising pretransit treatments and simulated transit temperatures were applied in a test shipment originated October 27, 1962 with white and red-fleshed grapefruit transported from Tampa, Florida, to Hamburg, Germany.

In this shipment, a uniform fruit temperature of 60° F. was attained after 2 days in the refrigerated hold and this was maintained throughout the transit period. The fruit temperatures in the ventilated hold were about 70° F. for the first 7 to 8 days and then gradually decreased to 45° F. The relative humidity ranged from 74 to 89 percent in the refrigerated hold and 55 to 95 percent in the ventilated hold. A slight build-up of carbon dioxide was noted in the refrigerated hold.

No rind breakdown developed in any of the test fruit during transit or during the 2-week holding period at 60°. Decay on arrival was 2 percent or less and 6 percent or less after 2 weeks' holding at destination. The rind of the washed-only (not waxed) fruit shipped under refrigeration and ventilation changed from green to an acceptable yellow color during transit. However, this unwaxed fruit shipped in ventilated stowage developed excessive shrivel.

A "containerized citrus export test" was conducted in cooperation with the Transportation & Facilities Research Division. Test grapefruit developed less than 1 percent decay upon arrival and only 3 percent after 1 additional week at 60° F.

2. Thermal Conductivity of Florida Citrus Fruit. Thermal conductivity values were determined for the rind and juice vesicles of Valencia oranges and Marsh Seedless grapefruit. The thermal conductivity values of the Valencia rind ranged from 1.0886 to 1.3394 BTU/hr/ft<sup>2</sup>/°F/in. and of the juice vesicles from 2.7968 to 3.3430 BTU/hr/ft<sup>2</sup>/°F/in. The thermal conductivity of the rind of the Marsh Seedless grapefruit ranged from 1.4091 to 1.8005 BTU/hr/ft<sup>2</sup>/°F/in. and from 2.8523 to 3.4875 BTU/hr/ft<sup>2</sup>/°F/in. for the juice vesicles.

3. Maintaining Quality of California Citrus in Transit. A test in California with the single-bunker, thermostatically-controlled, ice-refrigerated rail car revealed inadequate air movement through a chimney load of citrus fruit in cartons even though the air was ducted past the doorway. However, continuous operation of the fans in the single-bunker car cooled the fruit more than a conventional car with intermittent fan operation. At the end of a 36-hour precooling period the average fruit temperature was lowered 6 degrees more in the single-bunker than in the conventional car. This work has been completed.

#### 4. Effect of High Nitrogen - Low Oxygen Atmosphere on Bananas.

Tests were continued comparing the effects of atmospheres of 99% and 100% nitrogen, and air, on ripening, decay and firmness of green bananas. Bananas held in air at 60° F. for 7 days ripened completely in 3 days after being removed to air at 70°. Bananas subjected to 99% nitrogen for 7 days at 60° required 8 days after removal to air at 70° to ripen completely. When treated in 100% nitrogen, bananas failed to ripen when removed to air at 70°. Following treatment and 6 days' holding in air at 70°, check (air-stored) fruit had almost twice as much decay as those treated in atmospheres of 99% or 100% nitrogen. Firmness was highest at every inspection in those bananas treated in atmospheres of 99% or 100% nitrogen.

#### D. Postharvest physiology

1. Respiration of Florida Citrus Fruits in Relation to Postharvest Rind Breakdown. Brushing increased the rate of respiration of oranges. The increase in rate of respiration and in rind breakdown as a result of brushing was greater in the Pineapple variety than in the Valencias. Respiration rate and amount of rind breakdown increased as delay between time of harvest and time of brushing increased.

Hot water treatment of Valencia oranges increased the respiration rate and increased rind breakdown to about the same extent as did brushing.

Brushing and hot water treatments caused fruits to lose more weight than untreated fruit while, as expected, waxing decreased weight loss.

Waxing with commercial solvent waxes, either with or without sodium orthophenylphenol, had no apparent effect on respiration rates.

2. Postharvest Changes in Avocados and Papayas. Research under a P.L. 480 project in Columbia with avocados, primarily of the West Indian strain, shows 70° F. to be an excellent ripening temperature. Chilling injury often occurred at 50°. Fruits with highest oil content had the most resistance to chilling injury. Some moisture and oil determinations were made, but are inconclusive.

Papayas had best quality when ripened immediately at 65° F. They remained in good condition for 14 days at 50° but flavor deteriorated. Heat treatment for 20 minutes at 120° reduced decay and did not affect flavor or keeping quality. Fruits with some excess of sucrose over reducing sugars had the best flavor.

## E. Postharvest disease control

### 1. The Incidence and Nature of Biphenyl Resistance in Lines of *Penicillium Digitatum* and its Effects on Decay in Citrus Fruits.

Biphenyl content was determined for biphenyl-tolerant and biphenyl-sensitive clones of *Penicillium digitatum* cultured in atmospheres containing biphenyl vapors. In these investigations conducted in California the biphenyl-tolerant and biphenyl-sensitive cultures both contained approximately the same amount of biphenyl. Whether the biphenyl was adsorbed onto the fungus mycelial strands or absorbed into the protoplasm of the fungus cells was not determined. The answer to this question for both biphenyl-tolerant and biphenyl-sensitive strains of *penicillium* should be basic to further investigations of mode of action of biphenyl, and help explain the nature of tolerance in *Penicillium* strains.

### 2. Chemical and Non-chemical Control of Decay of California Citrus Fruits.

Green mold of lemons was as effectively controlled by immersion of the fruit in hot water as by several standard and experimental chemical treatments. Immersion of inoculated lemons in water ranging from 110° F. for 10 minutes up to 130° for 10 minutes or 135° for 1 minute gave good control of green mold rot. Severe rind damage occurred soon after lemons were treated at 135° for 10 minutes. Mild damage occurred after several weeks' storage, on lemons treated at 135° for 5 minutes, and slight damage after a longer period on lemons treated at 130° for 10 minutes.

### 3. Control of Postharvest Diseases of Florida Citrus Fruit.

Secondary-butylamine evaluated as a decay inhibitor for the second season in Florida, gave good results when used as a 1-percent dip and when incorporated in a wax emulsion. However, it was not consistently better than sodium-o-phenylphenate (SOPP), as now used commercially.

Hot water treatment for control of decay was further investigated for oranges and grapefruit. From 50 to 75 percent reduction of stem-end rot and green mold was obtained. The most effective temperature for immersion treatment was 127° F. for 5 minutes. A water temperature of 132° was required to give the same results when the fruit was flood treated. Decay control was increased by delaying treatment for 1 to 3 days following picking. However, rind breakdown of oranges was increased by this delay. Rind breakdown attributable to hot water treatment was not usually observed on grapefruit. Fruit which had been treated with hot water appeared to be more susceptible to reinfection or subsequent infection by *Penicillium* than did non-treated fruit.

Observations made on oranges harvested at weekly intervals before and after the freeze of December 12, 1962, revealed that minimum field temperatures of 20° to 22° F. had little effect on stem-end rot

development, but green mold was substantially increased after the freeze.

Ninety-four isolations of Phomopsis citri and 80 isolations of Diplodia natalensis were made from stem-end rotted fruit collected throughout Central Florida. These were tested in culture for reaction to biphenyl and SOPP. The Phomopsis isolates were relatively uniform in their growth habits and response to both chemicals. The Diplodia isolates were more variable ranging from complete sensitivity to moderate resistance. None were highly resistant nor immune.

4. Irradiation for Control of Postharvest Diseases. Radiation induced monauxotrophic, haploid, white, avirulent mutants of P. italicum were used for the preparation of weakly virulent heterocaryons. On minimal media, diploid, blue green, extremely virulent sectors were recovered. Haploid segregants from the diploid consisted of parental and recombinant types. Recombination resulting in prototrophy restored virulence. No gene linkage was detected between color and nutritional requirements. This is the first time a parasexual cycle has been reported for P. italicum and gives a rational basis for the introduction of new strains in this asexual fungus (conidial form).

Sixty-five color mutants of irradiated P. italicum and P. digitatum conidia (normally blue green and green) were classified into color groups. In general, virulence or avirulence could not be associated with a particular color phenotype. Approximately 44% of the color mutants of P. italicum and 67% of the P. digitatum mutants were virulent.

P. italicum and P. digitatum yielded 53 and 21 auxotrophic mutants respectively. Among the exogenous requirements for growth were: vitamin growth factors, purine and pyrimidine bases and amino acids such as adenine, methionine, cysteine, proline, lysine, inositol, pantothenic acid, nicotinic acid, biotin and choline.

The pectolytic enzymes of P. italicum and P. digitatum such as polygalacturonase (PG) and cellulase (Cx) have been demonstrated both in vivo and in vitro. Only virulent mutants produce PG and Cx in the orange while avirulent mutants produce only Cx.

Radiation induced mutants of A. fumigatus were not different from naturally occurring mutants in resistance to several chemicals. (MQ 2-32)

5. Control of Anthracnose on Mangos. Hot water treatments by immersion applied after harvest to five commercial varieties of Florida mango fruits (Zill, Haden, Sensation, Kent, and Keitt) showed

considerable promise as a control for anthracnose. The most effective hot water treatments involved exposures of about 5 minutes in water at 130 to 132.5° F. Fruit was damaged by treatments of longer duration and at higher temperatures. Treatments at 125° required 15 minutes exposure to reduce decay effectively. The different varieties of mangos varied in their susceptibility to damage from heat treatments. Flavor and natural ripening were not impaired by heat treatment.

6. Stylar-end Breakdown of Limes. Stylar-end breakdown was increased by handling incident to harvesting, sorting and packing. After storage for 21 days at 50° F. less than 4 percent of the limes obtained directly from the tree had stylar-end breakdown. Samples of fruit obtained from field boxes at the packinghouse had 9 percent of the disorder. In another test, fruit were intentionally bruised on the stylar end and stored for 21 days at 50° F. An average of 27% of the bruised limes were affected with stylar-end breakdown; only 6% of the non-bruised limes were affected.

Grove source was directly related to the extent of stylar-end breakdown. Of the total number of limes developing stylar-end breakdown during storage, 33% developed the disorder within 3 days after harvest and 75% developed it within 7 days.

Later in the harvest season when stylar-end breakdown was not prevalent, handling or intentional bruising of limes had no apparent effect on the extent of stylar-end breakdown.

7. Postharvest Diseases of Tropical Fruits. Under a P.L. 480 project in India a study is underway on the microorganisms which cause postharvest decay in mangos, guavas, bananas, sapodillas, litchis, papayas and pomegranates. This includes a comprehensive survey of the pathogens causing rots and the source of the inoculum. Several organisms which infect leaves and stems have been shown to also cause postharvest infections in fruit. Some organisms not previously reported as pathogenic have been shown to cause fruit rots. The carbohydrate substrates used by some organisms have been identified.

8. X-ray Detection and Identification of Incipient Infections. Studies with X-ray techniques for studying fruit infections are underway in Italy under a P.L. 480 project. The study has not progressed beyond rather gross studies of internal structure and a preliminary study of the course of infection by Penicillium glaucum. No evidence has yet been developed to indicate that X-ray techniques are useful for this purpose.

## PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance in Storage.

Chace, W. G., Jr., and Harding, P. L. 1962. Storage Requirements for Pope's Summer Orange. Proc. Fla. State Hort. Soc., Vol. 75, pp. 326-331. (MQ 2-51)

Quality Maintenance During Transportation.

Akamine, E. K., Shoji, K., Nakamura, M., Watanabe, H., Higoki, T., Cooil, B. J., Rygg, G. L., and Wells, A. W. 1963. Studies on Temperature, Humidity, and Other Factors During Handling and Transit as Factors Affecting Quality and Marketability of Papayas. Unnumbered Mimeo. Hawaiian Agricultural Experiment Station. (MQ 2-25)

Chace, W. G., Jr., Harding, P. L., and Cubbedge, R. H. 1963. An October Shipment of Florida Grapefruit from Tampa to Hamburg. Citrus and Vegetable Magazine, pp. 26-28. (MQ 2-74)

Hatton, T. T., Jr., Chace, W. G., Jr., and Harding, P. L. 1962. An April Test Shipment of Florida Grapefruit from Tampa to Hamburg. Citrus and Vegetable Magazine, pp. 26-28. (MQ 2-74)

Johnson, H. B. 1963. Truck-rail and Sea-land Shipping Tests with Texas Fruits and Vegetables. Marketing Research Report No. 589. (BS 2-165)

Postharvest Physiology.

Davis, P. L., Harding, P. L., and Sunday, M. B. 1963. Factors Affecting Rind Breakdown of Citrus Fruit. Marketing Research Report No. 596. (MQ 2-1)

Scholz, E. W., Johnson, H. B., and Buford, W. R. 1963. Heat Evolution Rates of Some Texas-Grown Fruits and Vegetables. Jour. of the Rio Grande Valley Hort. Soc., Vol. 17, pp. 170-175. (BS 2-141)

Postharvest Disease Control.

Rygg, G. L., Wells, A. W., Norman, S. M., and Atrops, E. P. 1962. Biphenyl Control of Lemon Spoilage. Influence of Time, Temperature, and Carton Venting. Marketing Research Report No. 569. (MQ 2-28)

Smoot, J. J., and Segall, R. H. 1963. Hot Water as a Postharvest Control of Mango Anthracnose. Plant Disease Reporter, Vol. 47, pp. 739-742. (MQ 2-68)

Wells, A. W., Norman, S. M., and Atrops, E. P. 1963. Measurement of Biphenyl Vapor. Jour. of Gas Chromatography 1(9):19-20. (MQ 2-28)

TRANSPORTATION AND MARKETING FACILITIES  
Transportation and Facilities Research Division, AMS

Problem. Returns to producers and prices paid by consumers for citrus crops are adversely affected by the use of inefficient marketing facilities, equipment, and methods. Better work methods, techniques, devices, operating procedures, equipment, and facility designs are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing citrus and subtropical fruit crops. Such improvements are needed at both shipping points and terminal markets. They would increase the productivity of labor, prolong the storage life of the commodities, reduce bruises and injuries to these products, reduce marketing costs, expand consumption, and reflect greater returns to producers.

It costs several billion dollars each year to transport farm products over the great distances between growing areas and consumers. In bridging this distance, products must normally be transported several times (farm to local assembly market, to warehouse, to terminal market, and thence to retail stores). Rail, truck, air, and water transport are used. Without this transportation, farm products would be worth little to farmers and nothing to consumers. Despite its importance, less has been done to improve the efficiency of transportation than for other aspects of marketing or farming.

USDA PROGRAM

This is a continuing long-range program involving engineering research covering the development of improved work methods, techniques, devices, operating procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing citrus fruits. Citrus fruit research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural Experiment Station, the Agricultural Research Service, Market Quality Research Division of AMS, and commercial packers. The current annual Federal effort devoted to research in this area totals 12.3 professional man-years of which 2.4 is on citrus fruits.

The Department has a continuing program of economic-engineering research in agricultural transport. Its purpose is to develop improved transport facilities, equipment and services and more efficient means of using them in the production and marketing of agricultural products. Almost all the work is carried out in cooperation with various industry groups, trade associations, State Universities and experiment stations. Only one field station, Orlando, Florida, is permanently maintained for transport research. All other field work is carried out from the Washington office. Part of the research under this program is conducted under contract and cooperative agreements. The current research in this area uses 11.8 professional man-years, of which 1.9 is devoted to loading methods and 0.5 to palletized and unitized loading of citrus.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Handling, Degreening, and Packing

This research, at Gainesville, Fla., is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling, and packing citrus fruits at Florida shipping points.

Three degreening tests of oranges, held in pallet boxes stacked four-high, were carried out with the cooperation of the Florida Citrus Fruit Experiment Station. It was found that fruit in pallet boxes degreened as well as fruit in the standard field crates stacked eight-high, or approximately the same height as the 4-high stack of pallet boxes. When using pallet boxes on concrete floors, it was found that better air circulation in the rooms was needed. Accordingly, a plan and sketch were made for testing an improved method of air circulation in degreening rooms using pallet boxes. However, the owner in whose plant this method was to be tested was unable to commit his facility to this project.

The trash eliminator-flow regulating unit designed and constructed, during the 1961-62 season, for use with the pallet box dumper was remodeled to better fit into space available in packinghouse equipment layouts. This remodeling included also the design and installation of a control gate in the hopper of the flow regulator. This control gate was for the purpose of achieving better regulation of the flow of fruit into the packing line. The specific objective was to provide a means of consistently discharging a single layer of fruit onto the inclined roller conveyor (with variable-speed drive) which delivered fruit to the packing line.

In limited test runs, the modified flow regulator fulfilled its purpose at relatively low packing line input rates. However, the dumper, obtained primarily for research purposes, was too slow for higher rates of flow needed for the packing line during certain periods. The hopper capacity of the flow regulating unit was not adequate. To maintain an even flow of fruit from a pallet box dumping operation, it was found that a flow regulating hopper must hold enough fruit to flow onto the take-away conveyor during the interval required to lower an empty box, replace it with a filled box in the dumper, and raise the filled box to the point where fruit begins to flow into the hopper again. Data indicate that a hopper capacity equivalent to at least  $1\frac{1}{2}$  pallet boxes is required. An article on the flow regulator was prepared and published. The operating experience with this equipment was limited because of the freeze of December 13, 1962, which halted packinghouse operations for the remainder of the season.

A manuscript was prepared and a report was published on methods of filling polyethylene film bags with citrus. It included an evaluation of two machine bagging systems, a mechanical bagging aid, and a manual bagging method. The results of this work made it possible for citrus packinghouse operators to have more comprehensive information on advantages and dis-

advantages when considering bagging methods relative to given needs and conditions. Potential annual savings for certain choices of methods ranged up to \$3,525 for packinghouses handling up to 200,000 master cartons (eight 5-pound bags) of oranges per season. Manual bagging methods were the most economical at annual volumes of less than 49,900 master containers of oranges packed in polyethylene consumer bags per season. The December 1962 freeze also hampered the work planned for this project.

### Cooling

Hydrocooling is the most widely used method for rapidly removing the field or harvest heat of such commodities as peaches, sweet corn, and citrus fruits. This method, however, presents certain problems--particularly in the case of citrus--where detrimental physiological effects sometimes result. Existing methods of hydrocooling are also cumbersome and inefficient. This research at Orlando and Gainesville, Fla., is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient precooling of fruits and vegetables.

The thermal conductivity test apparatus built at Orlando last year was slightly modified to facilitate the testing of citrus rind and juice vesicles. This made it necessary to re-calibrate and standardize the apparatus. Out of 65 test runs, the optimum series, involving 8 runs, produced a coefficient of variation of 5.8 percent and a percent error of the mean from the true value of 0.2. These results substantiate the technique for use without correcting for error. Subsequent tests with Valencia orange rind and juice vesicles resulted in thermal conductivities of 1.2184 and 2.9856 Btu's per hour, square foot, °F. per foot, respectively. The respective coefficients of variation were 8.43 and 6.87 percent. Similar results with Marsh grapefruit rind and juice vesicles produced conductivities of 1.6820 and 3.2094 Btu/hr., sq. ft., °F. per foot, respectively. Coefficients of variation were 1.64 percent for the grapefruit rind and 8.34 percent for the juice vesicle.

The pilot-scale forced-air precooling chamber at the University of Florida, Gainesville, was remodeled to improve the efficiency of operation in tests with 240-, 500-, and 100-pound loads of Hamlin oranges as compared to similar tests in 1961-62. This change made it possible to force all of the air through the coils and fruit in the container. A special container was designed and constructed with an aluminum frame so that the sides and bottom were removable to facilitate ease of filling and for testing standard wooden pallet bottom versus expanded metal bottom.

Three groups of experiments were carried out: (1) To ascertain differences in cooling rates between fruit place-packed in an orderly arrangement and random-filled in bulk; (2) to determine effects of various rates of air flow using three fan speeds and through a range controlled by a damper for each speed; and (3) to obtain rates of cooling in three types of consumer containers. Multipoint thermocouple probes were used in 40 tests with Hamlin oranges, Marsh and Foster grapefruit, and Orlando tangelos to determine temperature distribution within the fruit and location of the mass-average point.

Cooling rates for the place-packed vs. the random-fill were virtually the same. Thirty-eight tests with 500-pound loads, mostly with Hamlin oranges, some with Marsh and Foster grapefruit, and a few with Orlando tangelos, showed increased heat transfer with decreased rate of air flow between 12,000 and 2,500 CFM. The slower fan speeds resulted in greater heat transfer from the fruit with cooling efficiencies in our particular system of 30 to 40 percent at the slowest fan speed of 670 RPM.

Hamlin and Valencia oranges in 4/5-bushel wirebound boxes and 8-pound polyethylene bags (perforated) cooled nearly as rapidly as fruit in bulk. Fiberboard cartons cooled much more slowly.

Rind breakdown subsequent to cooling with air temperature below 18° F. was nil, except for one series with Orlando tangelos, for which center temperatures of below 25° F. were recorded. Neither rind breakdown nor an increase of decay was noted where final fruit surface temperatures were 25° F. or above. Loss of moisture amounted to about 0.2 percent per 90-minute pre-cooling tests.

### Handling and Packing Fruits on Terminal Markets

1. Tiering Devices and Equipment. This research also by the Washington office was directed toward reducing the cost of storing fruits and vegetables at the wholesale level by increasing the utilization of available storage space in wholesale fruit and vegetable warehouses.

The manuscript, "Storing Fruits and Vegetables on Pallets in Wholesale Warehouses," was edited for publication and forwarded to the Government Printing Office for printing.

2. Handling Operations for Multiple-Occupancy Facilities. The purpose of this research by the Washington office was to determine the combinations of crew sizes, operating methods, types of handling equipment, stacking or storage patterns, and facility layouts that will minimize the total cost of moving selected volumes of produce into, within, and out of modern multiple-occupancy buildings occupied by wholesale distributors of fruits and vegetables and reduce floor space requirements, and thus provide criteria to TFRD's Marketing Facilities Planning Staff for its work in specific areas or localities.

Work was limited to the completion of a "Survey of Fruit and Vegetable Wholesalers in Multi-Occupancy Facilities," covering 83 dealers in 11 cities in 10 different states. A summary has been prepared of the survey data, which include the business characteristic -- number of store units, annual sales, volume, seasonality of business, inventory, size, hours of operations, and services provide -- customer information -- type of customer, order size, and sale method -- and labor employed -- number of workers, wages paid, hours of work, crew size, and full or part-time workers.

Personnel assigned to this project have transferred and will not be replaced.

3. Loading Out Delivery Trucks. The purpose of this research is to evaluate and compare the relative efficiency of selected methods and types of materials handling equipment for order assembly and truckloading that are used by wholesale distributors of fresh fruits and vegetables supplying both affiliated and non-affiliated retail stores so as to reduce unit costs and minimize spoilage and waste.

This is a joint project of the Handling and Facilities Research Branch and the Wholesaling and Retailing Research Branch. Three basic types of loading out systems were studied in the warehouses of three wholesale distributors. The three methods include the use of: (1) A motorized belt conveyor with recording and transcribing equipment; (2) a motorized belt conveyor and checker system; and (3) a tow tractor and 4-wheel trucks to assemble individual orders. Preliminary analysis shows that the motorized belt conveyor with recorder and transcriber was less costly than other methods for the assembly of individual orders containing less than 55 packages. This system seems particularly suited for wholesalers supplying hotels, restaurants, institutions, specialty fruit and vegetable stores, and regular retail grocery stores. For wholesalers assembling larger than 55 packages per order, the tow tractors and 4-wheel selector trucks are the less costly. At the end of the year, a manuscript entitled, "An Evaluation of Selected Methods for Loading Out Produce in Wholesale Warehouses," which summarizes the results of this research, was in preparation for publication.

4. Improved Loading Patterns and Comparative Costs of Rail Piggyback Service for Citrus. This project consists of two parts. The initial study seeks development of improved loading patterns which will provide satisfactory cooling for citrus packed in the 4/5 bushel corrugated box. Relative high temperatures and unsatisfactory product condition experienced at destination markets in past years restricted use of the corrugated box even though its cost was 7-1/2 cents less than the same size conventional wirebound crate. The new air-stacked loading pattern resulted in savings of thousands of dollars per year to Florida citrus shippers in lower product loss and damage. Savings in container costs alone amount to more than \$300,000 each year. This new load pattern has been adopted by the Florida citrus industry for truck and piggyback shipments and approximately 90 percent of all Florida citrus packed in corrugated boxes is shipped in this manner. Some work also has been done on modifying the new loading pattern to make it more adaptable to new piggyback trailers. All field work has been completed and most of the data have been analyzed and results evaluated.

A second phase of the study of the movement of citrus has been undertaken to develop comparative data on freight and refrigeration costs for different sizes of loads and types of equipment. Information on the advantages, disadvantages and the patterns of utilization of rail-piggyback, straight rail and motortruck transportation also is being developed. The purpose of

this part of the study is to determine what improvements in transportation equipment and service are necessary to better meet the needs of the industry.

Field work during the forthcoming Florida citrus season, including interviews with railroads, truck operators, shippers and receivers, is planned. A detailed report will be prepared during FY-64.

##### 5. Preliminary Study of the Handling Practices and Equipment Used in Transporting Chilled Citrus Products.

Transit temperatures of chilled citrus products should be between 28 and 34 degrees to assure maintenance of original quality. Undesirable handling and loading practices, and the poorly designed refrigerated trailer equipment frequently used in transporting these products have resulted in heat pick-up during loading and inability to maintain desired temperatures during transit. A paired vehicle performance test was conducted from Florida to Massachusetts during the year. One shipment was handled in the usual manner while the recommended modifications in equipment and methods were used in the second. These modifications included the enclosure of exposed loading conveyors between warehouse and vehicle, installation of a plastic door curtain at rear of trailer during loading, and modification of the trailers front bulkhead at the refrigeration unit's blower to eliminate short circuiting of cold air during transit. As a result the modified load arrived at destination with an average product temperature of 29.6° F, whereas the conventional load had an undesirable average temperature of only 42.9° F. The carrier and shipper have since adopted most of the recommendations resulting from the study.

Two preliminary cooperators' reports have been prepared. A full report is being prepared for publication in FY-64.

##### 6. Preliminary Study of the Methods and Equipment Used in Handling and Overseas Transport of Agricultural Products.

A number of possibilities are being explored to increase U. S. exports of perishable agricultural commodities. The objective of this long range research program is to find ways to facilitate overseas delivery of high quality products at low costs. Preliminary observations were made of the practices, equipment, costs, and arrival conditions on a number of overseas shipments of perishables to determine some of the major problems which must be corrected to reduce transport costs and increase U. S. exports of agricultural perishables. Numerous problems were found in the present system of box-by-box handling in to and out of the refrigerated holds of ships.

The initial test shipment was a containerized refrigerated highway-type semi-trailer loaded with grapefruit which went from Florida to Basel, Switzerland. The elimination of numerous handlings and opening and closing of trailer doors during the 19-day transit period resulted in delivery of the product in excellent condition. Conventional shipments delivered at the same time sustained losses as high as 50 percent caused by the numerous

handlings and inadequate refrigeration. Several other containerized overseas shipments of perishables were tested in cooperation with the Department of Defense. These tests showed inconsistent results.

7. Preliminary Evaluation of Vented and Non-vented 4/5-Bushel Corrugated Boxes for Shipment of Florida Citrus in New Air-Flow Loading Patterns.

The vented box costs somewhat more than the non-vented box. The citrus industry wishes to determine whether ventilation holes substantially facilitates more effective cooling of product during transit. The results of two test shipments during the year indicated a slight increase in the rate of cooling for the vented boxes, but at the end of three days the difference in product temperatures between the vented and non-vented boxes was not significant. Additional laboratory and over-the-road tests need to be conducted under controlled conditions, both in storage and in transit.

8. Pallet Containers. During two shipping seasons, rail and truck test shipments were made with pallet containers of oranges and grapefruit from Florida to northern markets. This preliminary work demonstrated that potential savings derived from shipping these products in pallet containers as compared to the conventional wirebound and corrugated boxes were smaller than was found in the case for apples. A report was prepared and furnished to all cooperators in this research.

Work demands of other projects resulted in little or no pallet container work during the past year. A report on apples and an interim report on citrus are now in various stages of preparation for publication.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Handling, Degreening, and Packing Citrus Fruit

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Grizzell, W. G. 1962. A Device for Forming Two-Piece Telescoping Cartons. AMS-490, December 1962.

Grizzell, W. G. 1963. Filling Polyethylene Film Bags With Citrus Fruit. AMS-503, July 1963.

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Handling and Packing Fruits and Vegetables on Terminal Markets

Bogardus, R. K. and Lutz, J. M. 1962. Proper Storage Helps Keep That Farm Fresh Quality. SWD Bulletin, United Fresh Fruit and Vegetable Association, No. 228, November 15, 1962.

Bogardus, R. K. 1962. Signposts for Low Cost Handling of Fruits and Vegetables. Agricultural Marketing, Vol. 7, No. 12, December 1962.

Bogardus, R. K. 1963. Crew Organization Saves Dollars. Agricultural Marketing, Vol. 8, No. 2, February 1963.

Bogardus, R. K. 1963. Materials Handling Systems for Terminal Market Wholesalers. Paper presented at the Annual Convention, United Fresh Fruit and Vegetable Association, Los Angeles, California, February 11, 1963.

Loading Methods

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## COOPERATIVE MARKETING

## Marketing Division, FCS

Problem: Farmers continue to expand their use of cooperatives in marketing the products of their farms. In light of the rapid and complex changes taking place in technology and in market organization and practices, research is needed to help farmer cooperatives and other marketing agencies perform needed marketing services both more efficiently and more effectively. Farmer-directors, managers and others, including the public, need more information to assist in making decisions on how cooperatives can maintain and strengthen the bargaining power of farmers, increase efficiency and reduce costs of marketing, and better meet the needs of our mass distribution system for large quantities of products on a specification basis.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting farmers' marketing problems in our modern, dynamic system. They are organized and operated to increase farmers' net income. However, cooperatives face many problems in achieving this goal. Cooperatives must find ways to consolidate volume, for example, through internal growth, merger, acquisition or federation, to strengthen their market position and meet the needs of mass merchandising. Ways must be found to reduce costs by increasing efficiency through improved operating methods, better organization and management, and more use of new technologies.

## USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in cooperation with various State Experiment Stations, Extension Services, and Departments of Agriculture.

The number of Federal professional man-years devoted to research in this area totals 21.2, of which 1.0 man-years are on the cooperative marketing of citrus.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Coordination of marketing. To provide growers and shippers in the Florida avocado industry with basic information on which to make marketing decisions, a statistical analysis was completed of economic relationships affecting the industry's competitive position, including

sources of supply, utilization and consumption, distribution of sales and prices. Based on this analysis, a need for a marketing program which would coordinate harvesting, distribution and promotional activities was indicated. This would involve a consolidation of sales at the grower or shipper level in conjunction with the establishment of a central source of information on production, a marketing information service, a re-examination of advertising and promotional activities, and maintenance of rigid control over quality.

To provide information on methods of improving sales operations, research was initiated to assess the problems and possibilities of various types of joint sales programs that fresh citrus shippers in Texas might use to adjust to changing market conditions.

Pooling and pricing. Research was initiated to determine and evaluate the impact of the 1962 freeze on various types of pooling arrangements used in the Florida citrus industry and to provide information to marketing organizations on the advisability and means of adjusting conventional harvest and pooling arrangements to emergency situations. This work is being conducted by the University of Florida under contract.

Improved operating methods. To provide growers and shippers with guidelines that will help them adapt to changing marketing conditions, research is underway to determine the nature and extent of large scale buyers' requirements--particularly those made on a specification basis--for Florida fresh citrus.

Potentials incooperative marketing. Work is underway to analyze the present status and trends in the cooperative marketing of fruits, vegetables and nuts, and to evaluate the potential of cooperatives for increasing their operating efficiency and market effectiveness through integration, coordination, consolidation, expansion or other means.

#### **PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH**

Markeson, C. B. 1963. Economic Aspects of Marketing Florida Avocados. Marketing Research Report 614.

ECONOMICS OF MARKETING  
Marketing Economics Division, ERS

Problem. Most agricultural processing industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent years in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing, and distributing farm products. However, for producers and marketing firms to remain competitive additional information is needed on margins, costs, economics of scale and efficiencies possible in the marketing of farm products.

Marketing research also is increasingly concerned with evaluating present and prospective programs pertaining to agriculture, such as the Food Stamp Program and Federal Grading Activities and to the changing structure of market industries as this may influence the bargaining power of farmers. Research also is being directed to the economics of transportation and storage activities of both private firms and government. Increasing attention is being given to the longer-term outlook for various products and markets as an aid in better assessing the prospects for increasing industrial employment under the Rural Development Program and in assessing prospective interregional shifts in the areas of production and marketing for specific products.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural economists, economists, and personnel with dual economic and technical training engaged in research to determine the reasons for the changes that are taking place in marketing so that ways can be found to increase the efficiency of the marketing system and make it more responsive to changing public needs. This research covers all economic aspects of marketing from the time products leave the farm until they are purchased by ultimate consumers. It includes work on market potentials for new products and uses, merchandising and promotion, economics of transportation and storage, economics of product quality, marketing costs, margins and efficiency, market structure, practices and competition, and on information, outlook and rural development. In fiscal year 1963, 7.05 Federal professional man-years were utilized in this work on citrus and subtropical fruits.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### Market Potentials for New Products and Uses

#### Liaison Between ERS and Utilization Research, ARS

An agricultural economist is stationed at each regional Utilization Research and Development Division to provide liaison between the regional laboratories, ARS, and the Economic Research Service in order that economic research may be teamed with physical science research in approaching problems relating to new products and new uses. Phases of work are as follows:

- (1) To delineate the economic problems involved in developing markets for new and extended uses of commodities on which the laboratories are working;
- (2) to develop and assist in carrying out research studies for providing information that would aid the laboratories in deciding what particular products or processes would be most likely to be economically feasible; and
- (3) to develop and assist in carrying out research studies for appraising new products and processes developed by the laboratories, including studies of market potentials, comparative costs, and studies of the probable impact of new developments on sales and farm income.

#### Merchandising and Promotion

Effect of Special Promotions on Sales of Frozen Concentrated Orange Juice. A special promotion of frozen concentrated orange juice sponsored by processors during 1959 has been evaluated and the findings published. Changes in total promotion investment associated with this campaign are now being measured and will be related to changes in sales volume and returns to producers.

Also, a separate evaluation of a similar promotion conducted in 1962 has been completed. Findings showed that sales of frozen concentrated orange juice exceeded expected sales at existing prices by 2.5 million gallons during the period September through December 1962. Had a price reduction been used to gain this increase in volume, reduction in revenue at retail would have amounted to \$17.4 million as compared with the promotion campaign cost of \$3.5 million.

Consumer Purchases and Availability of Citrus, Citrus Products, and Other Products. This is continuing research in which data are obtained and published monthly showing volume of purchases, proportion of families buying, size and frequency of purchases, and prices paid for citrus and selected competing products. Annually, similar information is provided by geographic regions and family characteristics such as, size of family, presence and age of children, and age and work status of housewife. The data with analyses are supplied to a mailing list of approximately 1,400 producers, processors, marketing, promotion, and research agencies and others concerned with distribution of fruits, juices, and other food products. These data provide a basis for formulating and measuring the effectiveness of specific marketing

policies and procedures and in making decisions on allocation of supplies, pricing, merchandising, and promotion. Purchases of citrus have dropped sharply since December 1962, when a freeze severely damaged the Florida citrus crops. Since that time, prices paid for citrus and citrus products have risen but total consumer expenditure for fresh oranges and grapefruit and citrus juices have, in most instances, declined. Consumption of competing products, particularly other juices and drinks, have increased.

#### Effect of Solids Level on Consumer Acceptance of Fresh Florida Oranges.

Work is being initiated in cooperation with the Florida Citrus Commission to determine the effects of varying levels of solids in fresh oranges on consumer acceptance and purchases. This work was originally scheduled for the 1962-63 season but the severe freeze caused a temporary postponement. Indications are that some of the major retail chain buyers of fresh citrus are now specifying or considering buying fresh oranges with higher levels of solids than normally move in the fresh market. The experiment to be conducted in a sample of retail food stores will measure consumer acceptance of oranges of different solids levels with and without price differentials.

Market Development for Desert Citrus. The purpose of this research is to evaluate the potential of the Desert Citrus industry, identify major marketing problems, and appraise the effectiveness of alternative techniques to promote consumption of fresh citrus. Data have been collected and analyzed as a basis for estimating the potential supply of citrus by type and variety by 1967. Characteristics of local markets are described. Additional work is being developed in cooperation with commodity groups to evaluate alternative merchandising and promotion techniques for grapefruit and oranges. This work is being conducted under a Cooperative Agreement with the Arizona Agricultural Experiment Station.

Increased Produce Sales Through Improved Merchandising. Work has been started to review research conducted by the Department and other sources on retail merchandising and promotion of fresh produce. From this review, research findings applicable to improved retailing of produce will be condensed, assembled, and made available to retailers, commodity groups, and others involved in distribution of produce.

#### Economics of Transportation and Storage

Fruit and Vegetable Transportation. The volume of fresh produce shipped interstate from California-Arizona production areas has remained relatively constant since 1951. Total traffic handled by both railroads and trucks has averaged about 350 thousand carlot equivalents annually. Approximately 60 percent of the interstate shipments from California-Arizona origins moves to destinations east of the Mississippi River. About 32 percent moves to points west of the River, while 8 percent is dispatched to Canada and Mexico. In 1951 rail carriers handled 87 percent of the shipments to United States outlets and 93 percent of the traffic routed to Mexican and Canadian destinations. Since then, rails' share of the annual volume

shipped from California and Arizona to interstate markets has dropped to 70 percent and to 81 percent of the movement into Canada and Mexico during 1960. This loss by the railroads to trucks occurred primarily in that traffic moving to points west of the Mississippi River.

The ability of motortrucks to perform multiple pickup and multiple dropoff service, to make faster deliveries, and to offer greater flexibility for servicing less than truckload consignments were prime factors contributing to their success. Trucks are providing services that rails cannot duplicate economically.

The shipper survey phase of the two-part study is in manuscript form. The receiver phase will follow. Publication of the first phase is expected during the fourth quarter of calendar year 1963. Data are complete for the second phase.

### Economics of Product Quality

Feasibility of Radiation Pasteurization. The Atomic Energy Commission is interested in determining if radiation pasteurization of fresh strawberries, peaches, citrus fruits, grapes, and tomatoes is economically feasible. Preliminary results of this study indicate that under present marketing practices product losses in marketing channels are as high as 15 percent. Interviews with representative samples of packers, shippers, and retailers of these fruits indicate a definite desire for extension of shelf life of these products, possible through radiation pasteurization, and a willingness to accept such products. The marketing firms interviewed indicated that the major disadvantage of the process probably would be consumer resistance, but that this might be overcome through an educational program. Work is now in progress on the developments of estimates of the cost of radiation pasteurization to assist the AEC in developing designs for suitable equipment and facilities. This research is a part of the AEC program for expansion of the peaceful uses of the atomic energy.

### Marketing Costs, Margins and Efficiency

Marketing Margins. Marketing margins, retail prices, and farm values for fresh fruits and vegetables each increased 3 percent from 1961 to 1962. The farmer's share of the retail price for fruits and vegetables remained unchanged at 34 percent. Margins and prices for processed fruits and vegetables decreased. The farm value was down 12 percent, the retail price 4 percent, and the marketing margins 1 percent. The farmer's share of the retail cost dropped from 23 to 21 percent. A study of marketing margins for Washington Delicious Apples sold in Chicago and New York City showed the largest component to be the wholesale-retail margin. This margin claimed from 37 to 54 percent of the retail dollar in Chicago, and from 34 to 48 percent in New York City.

## Market Structure, Practices and Competition

Changes in Structure of Wholesale Fruit and Vegetable Markets. Direct buying of fresh fruits and vegetables from shipping points by retail chains, together with increased prepackaging, have had serious effects on the structure of the wholesale market for fresh produce.

A final report summarizing changes in the structure of 52 wholesale produce markets has been completed. Direct purchases from shipping point by chains and affiliated groups increased from 12 percent of total market receipts in 1936 to 26 percent by 1958. During this same period the number of produce wholesalers decreased by 15 percent.

There is a shift toward more specialized markets for fruits and vegetables as reflected by changes in the types of fruit being handled by auctions located in terminal markets and by the increase in consumer packaging. In addition, in the produce industry there is a shift in emphasis from "trading" to "merchandising." Many firms are giving emphasis to performing marketing services contributing to orderly marketing rather than attempting to profit from short-term changes in prices.

Changes in the Structure and Performance of the California Fruit and Vegetable Industry. Changes in the market structure and practices in marketing fruits and vegetables grown in California require producers, shippers and wholesalers to adopt lower cost methods and practices.

Particular attention has been given to an examination of the assembly and distribution of fresh fruits and vegetables including mode of transportation and composition of shipments. From 1955 to 1961 transportation of fresh fruits and vegetables shipped out of California by truck increased from 20 to 30 percent of the total volume. In 1961, shipments in mixed loads accounted for 65 percent of all trucks inspected at border stations--averaging 5.5 different commodities per load.

Marketing Agreements and Orders. While Federal market order programs have operated for many years, little economic analysis of their operations or results has been made. Guides are needed for determination of the usefulness and probable effects of selected market order provisions for various commodities and marketing conditions.

Activity has been confined to preliminary investigations with respect to the five currently active Irish potato orders, the date order, and the suspended Florida tomato order. Questionnaires have been prepared for interviews of potato and data market order managers and administrative committee members and a sample of Florida tomato producers and handlers. Available secondary data concerning the potato and date orders are being studied.

Competitive Relationships in Marketing Citrus Products. Serious marketing problems confront the citrus industry resulting from production in excess of demand.

In a study of competitive practices in marketing Florida and Texas grapefruit, buyers in eight major Midwestern markets thought increased production in Texas would affect Florida Interior more than Florida Indian River fruit. We can expect intense competition in marketing grapefruit as production increases.

A study of demand relationships for Florida and California Valencia oranges found no statistically significant substitution between fruit from the two areas. A 1 percent change in relative prices brought a 3 percent change in the relative quantities sold.

Structure of the Citrus Industry. Projections of the structure of the Florida fresh citrus industry to 1970 using both Markov chain and regression methods suggest fewer packer-shipper firms unless season average volumes double by then. Projections of size distribution generated from transition probabilities indicate that an increasing share of the total volume will likely be handled by the large firms.

### Information, Outlook and Rural Development

#### First Phase of Long-Term Outlook for Marketing Western Agricultural Products Relates to Fruits and Vegetables

Outlook for the marketing of fruits and vegetables for the 11 Western States was projected for the period 1975. These projections show a continued growth in the volume of these products and indicate that this western region should supply an increasing share of the total. The forecast is based on an expected increase of 31 percent in total U.S. population and some increase in per capita consumption per year. The West now supplies about 65 percent of noncitrus fruit, 45 percent of vegetables, and 28 percent of citrus fruits. Increases in the proportion of total supply of noncitrus fruits and vegetables, with a small decrease in the proportionate citrus fruits supplied by the West, appear in prospect. These changes can be viewed in terms of the total U.S. consumption increase projected for the period of approximately 33 percent above that of 1960.

The greatest growth including vegetable sales appears to be in processed products. The greatest growth in food and vegetable processing between now and 1975 is likely to be in freezing, combined freezing and dehydration, and various improved methods of dehydration. In these areas processing has grown rapidly and is likely to continue to grow for the next several years, though possibly at a slower rate.

## PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

### Merchandising and Promotion

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### Economics of Product Quality

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### Marketing Costs, Margins and Efficiency

Edman, Victor G. February 1963. Marketing margins for fruits and vegetables. Article in Marketing and Transportation Situation. (Reprinted as ERS-106.)

### Market Structure, Practices and Competition

Bohall, Robert W. April 1963. The organization of the wholesale fruit and vegetable markets in Miami and Tampa-St. Petersburg. MRR-593.

Chapman, W. Fred, Jr. October 1962. The organization of the wholesale fruit and vegetable markets in Seattle-Tacoma, Portland and Spokane. MRR-563.

Manchester, Alden C. June 1963. The changing market structure for perishables. Speech presented at Citrus and Vegetable Marketing Clinic, Lakeland, Florida.

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#### Information, Outlook and Rural Development

Martin, Loyd C. February 1963. Role of processing in utilizing all grades of products. Remarks at the Joint Session of Marketing and Horticulture Sections of the Association of Southern Agricultural Workers, Memphis, Tennessee.

Stallings, Dale G. March 1963. Marketing western fruits and vegetables, long-term outlook. ERS-77.

**ECONOMIC AND STATISTICAL ANALYSIS**  
**Economic and Statistical Analysis Division, ERS**

Problem. Because of the instability of the prices he receives and rapidly changing conditions of agricultural production, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for sound production and marketing decisions. It has long been a goal of the Department to provide the farmer with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting the principal farm commodities.

Producers, processors, distributors and consumers need better information on supplies, production and consumption of farm products, and the effect of these and other factors on the prices of these products. Similarly, Congress and the administrators of farm programs need to evaluate alternative proposals to modify existing price support and production control programs in terms of their impact on production, consumption and prices received by farmers.

### USDA PROGRAM

Commodity Situation and Outlook Analysis.

This work involves 0.5 professional man-year in Washington. The outlook and situation program involves continuous appraisal of the current and prospective economic situation of citrus fruits. Regular appraisals are supplemented by special analyses when needed. Results of these appraisals, findings of special analyses, and long-time series of basic data are published in the Fruit Situation, issued 4 times a year, and in brief reviews in quarterly issues of the National Food Situation and the Demand and Price Situation, and monthly in the Farm Index. A comprehensive analysis of the citrus fruits situation is presented at the Annual Outlook Conference. Presentations also are made at regional or State outlook meetings, meetings of farm organizations, and to various agricultural industry groups. Special studies are made from time to time to determine probable effect of proposed programs on supply, price and consumption of citrus fruits. Basic statistical series on stocks, foreign trade, consumption, and price are compiled, improved and maintained for general use in statistical and economic analysis.

## Supply, Demand and Price Analysis

This work involves 0.5 professional man-year located in Washington, D. C. The research is aimed at determining the price-consumption responses for fresh citrus and various citrus products, the competitive relationships among citrus products, the competitive relations among grades, and the relationship between citrus and noncitrus (including synthetic) products. The need for this information to aid in making marketing decisions has increased because of recent sharp reductions of citrus supplies.

### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

#### Commodity Situation and Outlook Analysis

The 1962-63 citrus crop (6.4 million tons), cut badly by winter freezes in all producing States, was about 25 percent smaller than the record 1961-62 crop and 18 percent below the 1956-60 average. As of late summer, prospects for U.S. 1963-64 crop oranges and grapefruit, especially in Florida, were less favorable than a year earlier due mainly to the freeze loss of limbs and trees. But prospects for lemons were better than a year ago.

High prices at all levels of sale for the reduced 1962-63 citrus crops have prevailed, especially since last December. Grower prices for Florida oranges and grapefruit and California lemons have averaged much above year-earlier levels. Prices for California oranges have fluctuated around high year-earlier levels.

The reduction in the 1962-63 citrus crop resulted in decreases in both fresh use and volume processed. Output of Florida frozen orange concentrate was less than half the 1961-62 record and the packs of the principal canned single-strength juices were down substantially. Packers' stocks during late summer were much below a year earlier, and prices at all levels of sale were up sharply. Reduced U.S. supplies of fresh and processed citrus at increased prices during 1962-63 have resulted in decreased exports of fresh oranges, grapefruit, and lemons and of most processed items. At the same time, there were increased imports of fresh oranges and concentrated lemon juice.

New indexes of production and prices of citrus fruit, beginning 1935, were included in the Fruit Situation, January 1963. The new indexes (1957-59=100) replace old indexes (1935-39=100). Long-run projections (5 years) were developed for citrus fruits as part of a set of ERS projections for the economy as a whole.

An article, prepared in the Marketing Economics Division of Economic Research Service, evaluated survey data relating to fruit consumption under the food stamp program conducted in Detroit, Michigan, and rural Fayette County, Pennsylvania, in 1961. It showed that total consumption of all fruit and fruit juices (fresh fruit equivalent basis) by families using food coupons increased over previous consumption.

### Supply, Demand and Price

A study of price differences of Florida oranges sold for fresh market due to differences in quality in relation to quantities shipped was made for postwar years. Various formulations were tried, including comparisons between Indian River and Interior oranges and between No. 1 and No. 2 grades. Indian River orange prices were higher than Interior prices by a fairly constant amount which did not seem to be related to quantities shipped fresh from each area. Very small shipments of No. 2 oranges during the postwar period, particularly in the last 10 years, made it difficult to determine a meaningful relationship between No. 1 and No. 2 prices and quantities. In most years No. 2 oranges were shipped only at the end of the season, and in a few years during the first couple weeks of the season, when all fresh oranges prices were higher than in the rest of the season. In addition, the proportion of total fresh shipments contributed by the different areas and types of oranges differed considerably from year to year. In general, Valencia oranges sell for more than Early and Midseason oranges, and Indian River fruit for more than Interior fruit at any given time during the season. Even though several adjustments were made in the data to compensate for these difficulties, the results were inconclusive.

### PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

#### Commodity Situation and Outlook Analysis

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION--  
HOUSEHOLD AND INDUSTRIAL  
Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D.C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

The Federal scientific effort devoted to research in this area during the past year totaled 7.0 professional man-years, of which 0.2 was devoted to work on citrus and citrus products.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### Consumer Preference

A representative of the Branch continued to serve as consultant to assist in analysis of data and the preparation of a report on the results of a taste test and a household survey in West Germany. The purpose of these studies is to aid Florida citrus processors in determining the most desirable sugar-acid levels in packs of canned single-strength citrus juice for export and in understanding attitudes of European consumers toward the use of citrus products.

### Quality Discrimination

Although there is growing evidence that retailers are placing more emphasis on the internal qualities of fresh oranges, there is no information to indicate which specific characteristics are discriminable and preferred by consumers. Planning was begun on taste tests in which one or more panels of people will be asked to taste fresh orange juice samples which have different Brix-Acid levels. The purpose of these tests would be to determine between which brix and acid levels significant discrimination occurs, so that non-discriminable combinations may be eliminated from subsequent consumer preference studies. This research into consumer reactions to various tart-sweet combinations would provide growers and other segments of the trade with guidelines whereby they could select the most desirable tart-sweet levels of fresh oranges for the consumer market.

Producers of fresh citrus receive lower prices for fruit claimed by wholesale dealers to be objectionable to consumers and therefore to affect adversely their demand for fresh citrus. Planning was begun on a study to determine (a) how household consumers and representatives of various levels of the food distribution trade, including wholesalers and retailers, evaluate quality in fresh citrus fruit, (b) reactions of the trade and consumers to fresh citrus with specified visible defects, and (c) the misconceptions, if any, in the opinions of the trade about what characteristics consumers consider desirable and undesirable in fresh citrus. Further work on this study was delayed because the severe freezes in the principal citrus growing areas during the 1962-63 season prevented the shipment of fruit with characteristics suitable for testing.